KENTUCKY GEOLOGICAL SURVEY

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IN CO-OPERATION WITH

UNITED STATES GEOLOGICAL SURVEY

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GEOLOGY OF
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GEOLOGY AND MINERAL RESOURCES OF JEFFERSON COUNTY, KENTUCKY.

BY

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CHAPTER 1.

INTRODUCTION.

LOCATION AND EXTENT.—Jefferson County, Ky., is located in the northern margin of the state about midway of its length. Its location and shape are shown on the index map, Fig. 1. Its area is 387 square miles.

HISTORY AND POPULATION.—This county, as at present limited, is part of the original Jefferson County, which was one of three divisions of the territory of Kentucky established in 1780 by the State of Virginia, to which the territory then belonged. The other two counties were Lincoln and Fayette. From time to time other counties were set off from the original Jefferson County, the last being Oldham County, which was created in 1823, leaving Jefferson County with its present limits.

The first settlement in the county was made on Corn Island, opposite Louisville in 1778, in connection with the military expedition against Kaskaskia under the command of General George Rogers Clark. Late in 1778 or early in 1779 the settlement was moved to the mainland and located in the vicinity of the point where 12th street now intersects the river. Thus was founded Louisville, which has grown to be the twenty-third city in the Union, with a population of 223,928 in 1910. The population of the county in 1910 was 262,920. The original settlers were English from Virginia, and the present population of the county is largely composed of the same stock, with which is intermingled, however, a large German element of more recent arrival.

INDUSTRIES.—The principal industries are manufacturing, commerce, agriculture and quarrying. A large part of the surface of the county is occupied by excellent farming and grazing land. Corn, wheat, and potatoes are the principal crops, and dairying and stock raising are extensively carried on. But a small part of the area is woodland, which is mostly confined to the stream bluffs and steeper slopes and rough land, such as the knobs in

the southern part of the county. The county has no high grade mineral deposits, such as gold, coal, etc., but has an inexhaustible supply of limestone excellently adapted for building stone and road metal, and an abundance of clay and shale for brick, tile and cement. Quarrying, and brick and cement manufacture, are therefore, the principal mineral industries. There is sufficient water for ordinary industrial and domestic uses, and a large potential water power at the "Falls of the Ohio."* These subjects are treated more thoroughly in subsequent parts of this report.

GEOLOGY.—Geologically the region is an extremely interesting one. The "Falls of the Ohio" is one of the most famous localities in the world for fossil corals, some of the limestone beds being old coral reefs literally crowded with the coral remains. In number of species and of excellent specimens this great burial ground of the inhabitants of this region in a far distant age is perhaps unrivaled in any other part of the world. Other parts of the county and other strata are almost equally rich in fossils which record the ancient life of the seas that overspread the region, perhaps twenty million years ago. It will be the object, in part, to present in the following pages the story to be drawn from these ancient records as preserved in the rocks of the county.

PLAN OF REPORT.—This report is divided into five main parts, as follows: Introduction, in which are treated matters of general import and the general geologic and physiographic relations of the county; Topography, under which the surface relief and drainage are described; Descriptive geology, in which the character and distribution of the various rock formations are described; Historical geology, where the progress of events recorded in the rocks is related; and, Economic geology, under which are discussed the geologic deposits useful to man and their exploitation.

ORGANIZATION AND ACKNOWLEDGMENTS.—The survey upon which this report is based was made in the summer of 1914, as a joint work of the Kentucky Geological Survey and the U. S. Geological Survey, each organiza-

*See Water Resources on subsequent pages.

tion bearing one-half of the expense. The survey was conducted by the writer in association with Dr. Thomas C. Brown, of Bryn Mawr College, and Dr. J. J. Galloway, of the Indiana State University. To these gentlemen the writer is especially indebted for efficient assistance. Acknowledgment is also due to Mr. J. B. Hoeing, the State Geologist of Kentucky, for his active co-operation; to Dr. A. F. Foerste, whose writings have been freely consulted, and drawn upon for illustrations of fossils; to Dr. Stuart Weller for illustrations of fossils; to the late Henry Nettelroth, and to William J. Davis, both of Louisville, for fossil lists and illustrations, and to E. O. Ulrich, George H. Girty and R. S. Bassler, for study of fossil collections and assistance in stratigraphic determinations, etc. The writer also expresses his appreciation to Mr. White, Chief Geologist of the U. S. Geological Survey; and to Mr. Keith, Chief of the Section of Eastern Areal Geology, for the opportunity to undertake this work and for their hearty support in its prosecution.

GENERAL RELATIONS.—In its general physiographic and geologic relations Jefferson County lies in the grand natural division known as the Appalachian Province, all parts of which have had a common history, which is recorded in its rocks and surface features.

Just as the political history of Jefferson County can be understood only in connection with the history of the United States with which it is inseparably bound up, so the geologic features of the county can be understood only through a knowledge of the broader geologic features of the great province of which the county is a small part. Therefore a short description of the Appalachian Province is given here.

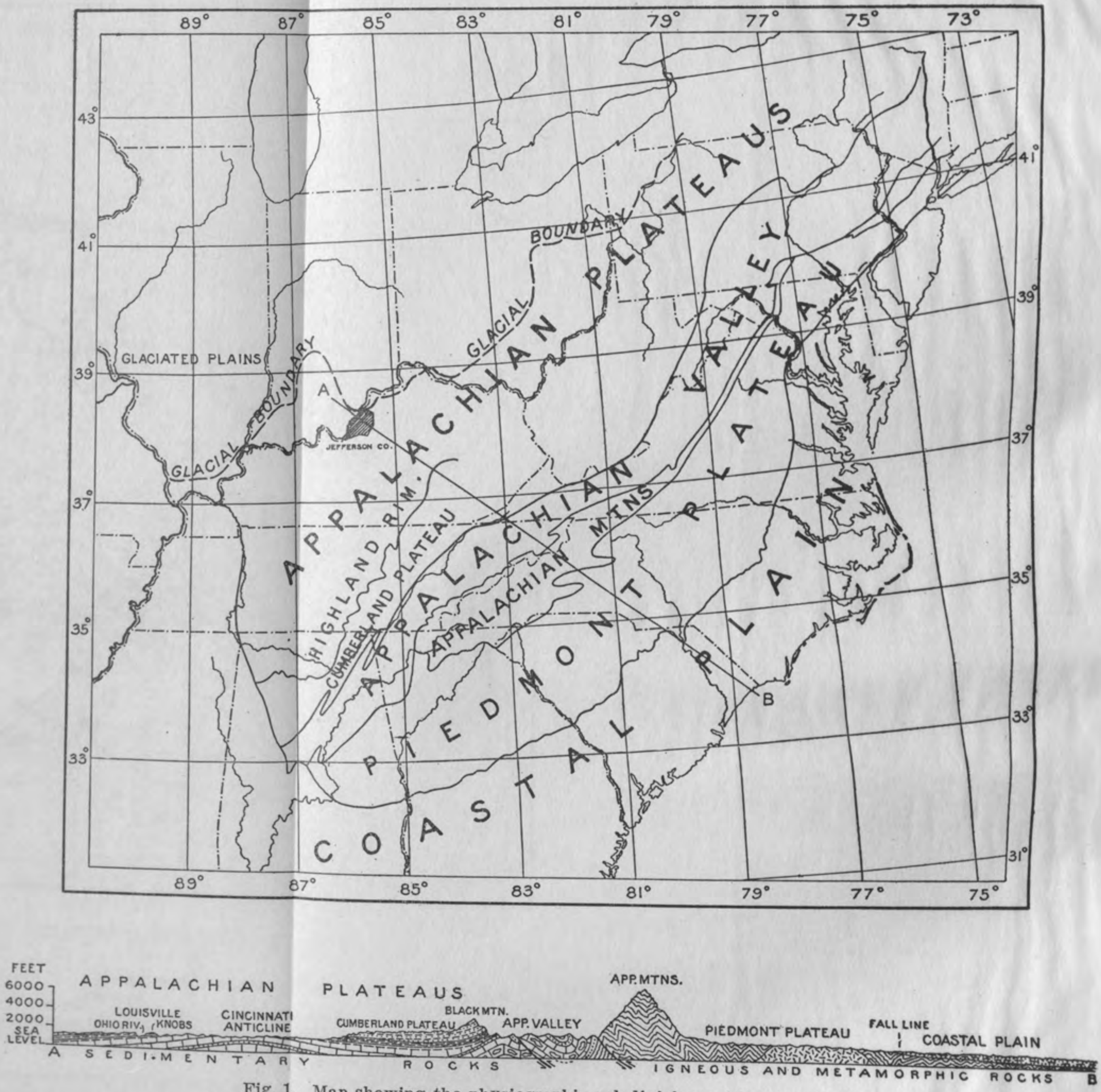


Fig. 1. Map showing the physiographic sub-divisions of the Appalachian Province and the location of Jefferson County, Ky., with an ideal section along the line A. B. Vertical scale of section greatly exaggerated. Jefferson County represented by the shaded area.

CHAPTER 2.

GEOLOGY AND PHYSIOGRAPHY OF THE APPALACHIAN PROVINCE.

PHYSIOGRAPHY.

Definition.—The Appalachian Province extends from Canada to Central Alabama and from the Atlantic coastal plain on the east to the Mississippian lowlands on the west, the western limit being very indefinitely located.

Divisions, Subdivisions, and Relief.—According to relief and geologic structure the Appalachian Province naturally falls into a number of subdivisions. In a broad way it is divided into two nearly equal parts by the great eastward-facing escarpment known in Pennsylvania as the Allegheny Front, and in Tennessee as the Cumberland escarpment. East of this escarpment the strata are generally highly inclined, as the result of folding and faulting. They have been squeezed up into great wrinkles called folds, and deep, long breaks, called faults, occur, along which are great dislocations of the rocky beds. (See Section, Fig. 1.) West of the escarpment the strata are, with some exceptions, so nearly horizontal that any inclination can be detected only by careful measurement.

Appalachian Valley.—Immediately east of the general escarpment is a belt of country 40 to 125 miles broad characterized by alternating deep valleys and high ridges trending rather uniformly in a northeast-southwest direction and in general lower than the highlands on each side presently to be described. This division of the province is called the Appalachian Valley.

Appalachian Mountains.—East of the Appalachian Valley is a mountainous tract culminating in Mt. Mitchell, N. C., 6,711 feet high. This division is named the Appalachian Mountains. The famous Blue Ridge lies along

the east side of this division in Pennsylvania, Virginia and the Carolinas.

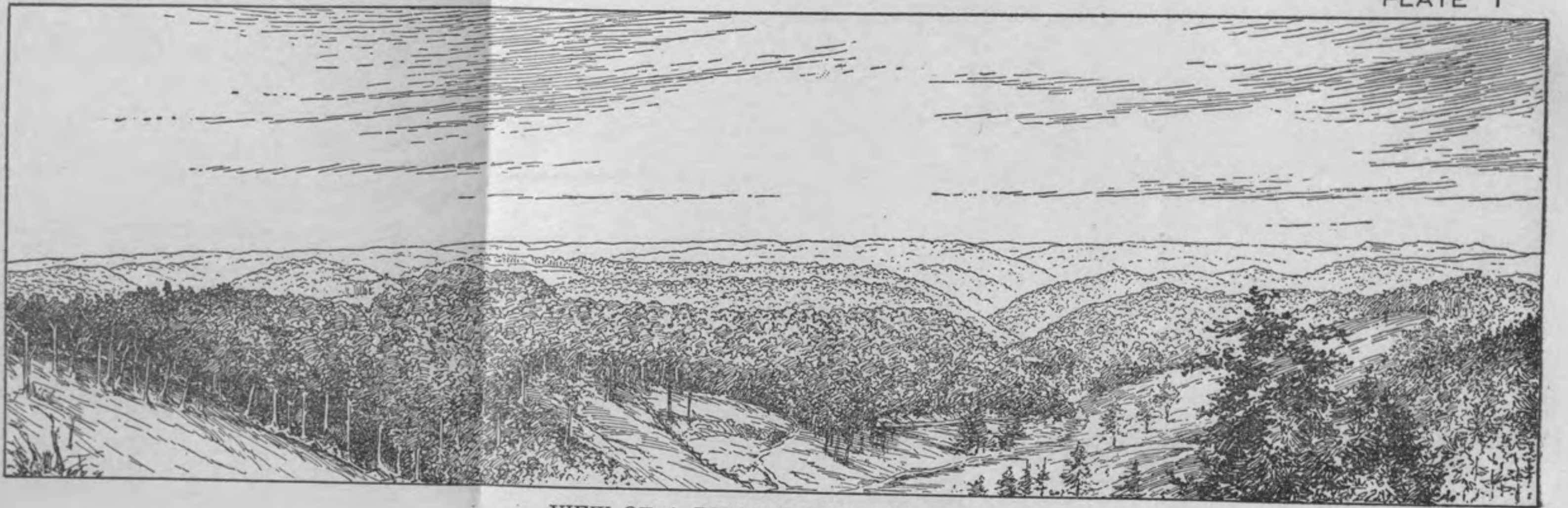
PIEDMONT PLATEAU.—East of the Appalachian Mountains is an upland furrowed by shallow valleys. This upland is about 1,000 feet above sea level along its west side and slopes gradually eastward and southward to the Atlantic coastal plain. This is the Piedmont Plateau.

APPALACHIAN PLATEAUS.—Immediately west of the Allegheny Front-Cumberland escarpment and extending to the Mississippian lowlands in Kentucky, Indiana and Ohio, are a number of more or less definite highland or upland surfaces which are known collectively as the Appalachian Plateaus, and which constitute about one-half of the Appalachian Province. The word plateau, which means a broad, flat, elevated area or table land, is, with exceptions noted beyond, rather a misnomer as applied to this division of the province. While true plateaus probably once existed over most of the region, they have been so trenched by the streams that the present condition of most of the area is that of high hills whose summits approach the original plateau surface, separated by deep valleys. In other words, the more accurate designation for most parts of the area is dissected plateau. Still more appropriate, though more general terms, would be the designations uplands and highlands, the application of the one or the other depending upon the general altitude of a given region. The dissected plateau feature is displayed in Plate 1.

The Appalachian Plateaus fall naturally into two main divisions, a highland division on the east immediately west of the Appalachian Valley, and an upland region still further west in Ohio, Kentucky and Tennessee. The dividing feature in Tennessee is the pronounced western escarpment of the Cumberland Plateau, descending 800 to 1,000 feet to the Highland Rim. From central-eastern Kentucky to Western New York the highlands and uplands are less definitely separated than are the Cumberland Plateau and the Highland Rim. There appears, however, to be a relatively abrupt slope between the general level of the highlands and that of the uplands extending through a wide belt passing in a general way east of Charleston, W. Va., through the

southwest part of Pennsylvania to the western end of

... distinct area preserving in a large degree the original features of a tableland, the highland belt partakes of the nature of a greatly dissected plateau having high hills, deep valleys and steep slopes, and in Kentucky, Virginia, West Virginia and Maryland, narrow-crested ridges and generally small, sharply-rounded hill tops, while further north in Pennsylvania and New York the ridges and higher surfaces generally are much



VIEW OF A DISSECTED PLATEAU.

View was taken at Clintwood, Dickenson County, Va., looking east, and shows a dissected plateau with general surface coinciding with the surface of an uplifted peneplain, as shown by the even skyline.

the east side of this division in Pennsylvania, Virginia and the Carolinas.

PLATE I

central-eastern Kentucky to western New York the highlands and uplands are less definitely separated than are the Cumberland Plateau and the Highland Rim. There appears, however, to be a relatively abrupt slope between the general level of the highlands and that of the uplands extending through a wide belt passing in a general way east of Charleston, W. Va., through the

southwest part of Pennsylvania to the western end of New York. The eastern boundary of the uplands is placed at the foot of this slope and follows a course approximately parallel to the Ohio River through W. Va., and thence follows the Ohio-Pennsylvania boundary to the southwest corner of New York. Approximately this boundary separates the country on the west, most of which lies between 1,100 and 1,300 feet above sea level, from the country on the east above 1,300 feet, and gradually rising eastward to a rather wide belt at an altitude of about 1,800 feet.

HIGHLAND REGION.—The highest part of the highlands is in Pocahontas County, W. Va. In this county there are considerable areas over 4,000 feet in altitude, and the extreme elevation seems to be over 4,700 feet above sea level. Its elevated character is shown by the fact that Potomac, James, Elk, Gauley and Greenbrier rivers radiate from it. From this central elevated region the general surface slopes westward to the upland at 1,100 to 1,300 feet from New York to central-eastern Kentucky, and southwestward to the western escarpment of the Cumberland Plateau in Tennessee and Alabama. From this central elevated region it also slopes northward to altitudes varying from 1,800 to 2,400 feet in southwestern New York, and southward to an altitude of about 2,000 feet on the Cumberland Plateau, to heights between 1,300 and 1,500 feet in Lookout, Blount and Sand Mountains in Alabama, and finally to about 500 feet above the sea at the border of the Coastal Plain in Alabama. With the exception of a comparatively small area south of Blount Mountain in Alabama, this whole division of the Appalachian Plateaus from central-western New York southward is distinctly a highland.

With the exception of the Cumberland Plateau, which is a rather distinct area preserving in a large degree the original features of a tableland, the highland belt partakes of the nature of a greatly dissected plateau having high hills, deep valleys and steep slopes, and in Kentucky, Virginia, West Virginia and Maryland, narrow-crested ridges and generally small, sharply-rounded hill tops, while further north in Pennsylvania and New York the ridges and higher surfaces generally are much

broader and the slopes are much gentler than in the first named areas.

UPLAND REGION.—The upland region extends from northeast Ohio to southern Tennessee and westward to the Mississippi lowlands. Disregarding the larger valleys and the higher hills, the general level of the uplands is 1,000 to 1,300 feet, and viewed broadly presents the aspect of a gently undulating plain. The Highland Rim in Tennessee and southern Kentucky, and the Lexington Plain in Central Kentucky are specially named parts of the upland region. These are names of long standing and are well understood local designations.

The Highland Rim is a plateau-like surface of considerable width and 1,100 to 1,300 feet above sea level, bordering the Cumberland Plateau on the west and terminating rather abruptly westward at the Nashville Basin in Central Tennessee. The original plateau character of the upland region is best preserved in the Highland Rim.

The Lexington Plain is named from Lexington, Kentucky, in which region it is extensively and typically developed. The larger part of an extensive area in this region lies between 900 and 1,000 feet above the sea; and in a wide, distant view, in which the effect of the valleys does not appear, has the aspect of a plain. In reality it is a more or less deeply and minutely dissected plain or level upland, whose original character as a plain, before the valleys were eroded into its surface by the streams that traverse it, is palpably apparent on such a wide view as mentioned above. The Lexington Plain formerly extended westward over Jefferson County, but owing to the proximity of the region to Ohio River, with consequent more active stream cutting and erosion, most of the present surface of the county has been reduced below the general level of the plain. The higher ridges at 750 feet altitude in the western part of the county are 150 to 250 feet below the original level of the Lexington Plain. The higher knobs in the south-western part of the county at 800 to 900 feet altitude approach close to the level of the plain, and knobs on the bluffs immediately west of Ohio River in Indiana at 940 feet and a surface at 1,000 feet a few miles farther west,

probably may be considered as remnants of the Lexington Plain.

Overlapping the northwest margin of the uplands is the glaciated area over which the ice sheet of glacial times extended to a southern limit passing near Cincinnati and southward just southeast of Ohio River nearly to Louisville, whence it runs northwestward two-thirds of the distance to Indianapolis. These limits are shown on the map, Fig. 1. This proximity of Jefferson County to the glaciated area is of importance in connection with certain geologic features to be later described.

GEOLOGY.

ROCKS.—The rocks of the Piedmont Plateau and Appalachian Mountains are mainly crystalline rocks, such as granite, diorite, gneiss, schist, diabase, etc. Probably the larger part of these crystalline rocks are the oldest in the province and among the oldest in the world. They are supposed to have originated in the Archean period, as the most ancient known period of the earth is named. So likewise in this eastern region existed one of the most ancient known land areas or continents from which was derived the sediment forming a large part of the younger rocks of the Appalachian Valley and of the Appalachian Plateaus.

The rocks of the Appalachian Valley and of the Appalachian Plateaus, including Jefferson County, are sedimentary, that is, they were formed as sediments washed from dry land and spread out as great sheets either on the bottoms of the seas or upon the low lands between the mountains and the seas. Owing to their mode of formation they are arranged in layers, or stratified. They are mostly of three kinds, sandstone, made up of fine grains of silica (quartz); shale, made up largely of very fine clayey material; and limestone, which is carbonate of lime extracted from solution in the water bodies largely by various organisms for their hard parts, such as the shells of molluscs and the hard parts of corals, or precipitated by bacterial action. The rocks of Jefferson County are mostly limestone. There is a less amount of shale and very little sandstone. The absence of sandstone is explained by the fact that the region was distant from dry land while its rocks were being deposited, so that sand, being somewhat coarse and heavy, was not transported to it, but deposited nearer the shore of the sea that covered the country at that time. On the other hand the absence of sediment left the water clear and on that account favorable to the growth of the animals which extracted from the water the lime which it held in solution and freely disseminated throughout the water body. Hence the predominance of limestone in this region.

GEOLOGIC STRUCTURE.—In the Piedmont Plateau and the Appalachian Mountains the rocks are very strongly disturbed, being upturned from the horizontal position in which they were formed, and folded, puckered, faulted, etc.; in the Appalachian Valley they are also strongly folded and faulted and the strata of sandstone, limestone and shale stand at all angles from horizontal to vertical, and in extreme cases bent over beyond the vertical, so that now they are inverted; in the Appalachian Plateaus the strata are as a rule horizontal, or very gently inclined. There are a few folds and faults of considerable magnitude in the highland belt, and one large, dome-like swell in the upland region known as the Cincinnati Arch. Jefferson County is located on the west limb of that dome, so that its rocks have a moderate westerly dip.

GEOLOGIC HISTORY.—As far back in time as any evidence exists on the subject, the surface of the earth has been divided into land areas and water areas. Either by rivers or by the sea acting along the coasts, sediment has always been transported from the land areas to the water areas and there deposited in layers to become the stratified sedimentary rocks of succeeding times. Excepting certain deposits which were laid down on land by flood waters of streams or by winds and which can usually be recognized as of such origin, all sedimentary rocks are deposits in bodies of water. The presence of sedimentary rocks of a subaqueous origin of a given age in a given area, is conclusive evidence that the area was covered by water during the given time, and conversely the absence of such sedimentary rocks of a given age, from any area proves that the area was dry land either during that age or at an immediately subsequent time. According to the first supposition no rocks were deposited; according to the second supposition, if rocks were deposited in the area in the given time, the area was subsequently raised above water and the rocks eroded away. Hence it must be plain to the reader that the distribution of the sedimentary rocks of subaqueous origin affords data for the reconstruction of the geography of bygone ages so far at least as the distribution of land and water is concerned. The actual distribution of the rock formations has shown, in accordance with principles stated above, that there has been a constant rearrangement of

the land and water areas of the earth's surface during geologic time, that parts of the dry land of one age have been submerged by a sea or lake of a later age, and so on from the beginning until the present.

The earliest condition still clearly defined in the history of the Appalachian province is that of dry land throughout North America, except on the western coast and in a narrow trough occupied by the sea which extended from the St. Lawrence River, passing near, but east of, the Kentucky-Virginia line, to Central Alabama and the Gulf of Mexico. In this trough the earliest fossiliferous rocks of the Eastern United States, those of Lower Cambrian age, were deposited. Subsequently the interior of the United States, including the Kentucky region, slowly subsided with more or less gentle warping which permitted the sea to overflow various low-lying areas, so that comparatively shallow seas of irregular pattern, separated wholly or partially by land barriers, overspread the country. These seas continuously received deposits of sand, mud and lime carbonate that in time were hardened into strata of sandstone, shale, and limestone. This partly submerged area was bounded by large land areas in the Canadian region on the north; in the region of the Appalachian Mountains on the east; and in the region of the Ozark Mountains on the west. The Appalachian Mountains area probably extended eastward into the Atlantic and possibly over the larger islands of the West Indies from Cuba to Porto Rico. From these bordering highlands was derived the larger part of the sediment that later was converted into the stratified rocks of the subsiding interior area. The gradual sinking of this interior area, with warping and shifting of sea and land, went on throughout all the remainder of Paleozoic time, and the sediments washed in from the lands or derived from the lime carbonate in solution in the sea water accumulated in places to the thickness of 30,000 feet or even more. In the Louisville region, however, it is not likely that the full thickness of sedimentary rocks ever exceeded 5,000 or 6,000 feet. At times the whole interior may have been covered with water and then there existed a great interior Paleozoic sea.

The Carboniferous was the last period of the Paleozoic (ancient life) era. This period was the time of the principal coal formation east of Mississippi River, and its rocks include nearly all the important coal beds in that part of the country. While the coal bearing rocks once possibly extended over Jefferson County and the coal areas of Eastern and Western Kentucky may have been continuous, these rocks if ever present, have since been eroded from all Central Kentucky, so that the two coal areas are now separate, and only older and lower rocks are now present in Jefferson County.

At the close of the Carboniferous period the eastern portion of the United States was permanently raised above the sea and with the exception of the margins along the Gulf of Mexico and the Atlantic Ocean, has so remained ever since. This uplift is commonly known as the Appalachian revolution. This elevation of the continent was attended by strong folding and faulting of the formerly horizontal strata of the Appalachian Valley.

Throughout most of the Appalachian Plateaus, however, the rocks are scarcely disturbed from their original horizontality. The principal deformation in the western part of this region is the Cincinnati Dome mentioned on a previous page, which was probably in the main developed at the time of the Appalachian revolution as a great upward swelling of the crust in Southwestern Ohio, Southeastern Indiana, and Central Kentucky, the axis of which passes near Cincinnati, O., and Lexington, Ky. It is certain, however, that a low dome in the strata had already existed in that region in earlier times.

The Paleozoic was in the main a constructive era in the history of the Appalachian Province. Strata were built up. Subsequent time has been marked by destructive action in this province. Strata have been disintegrated and washed away by running water. The process is still active, in proof of which it is only necessary to call attention to the muddy streams at flood times, the turbidity of which is caused by the earthy matter in suspension washed down by the streams from the higher ground. The ultimate destination of the sediment in the muddy water in that region is the Gulf of Mexico, where it settles to the bottom in great sheets to become the stratified rocks of succeeding ages.

It is easy to see that, if uplift does not take place, the Appalachian Province would, by the continuance of the process just outlined, in time, though a very long time indeed, be worn down nearly to sea level and be reduced thus to a great low-lying plain. If, however, the time were not long enough for the complete reduction of the country, most of it would be so reduced, while here and there would be left an unreduced remnant standing above the general level. Such a remnant might be an especially hard and resistant rock mass or an area near the headwaters of the rivers. The operation by which this effect is wrought is conveniently expressed by the word degradation, or erosion, and the final result is called a peneplain, meaning almost a plain.

There is satisfactory evidence that there have been at least two main periods of extensive erosive degradation in the Appalachian Province since the Appalachian revolution, and there is also much evidence of others of both earlier and later date. This first period may be regarded as beginning when the country became land at the time of the Appalachian revolution and continuing throughout the Triassic and Jurassic periods and perhaps into the early part of the Cretaceous period. As the result of this long continued erosion, the province seems to have been very widely reduced to a peneplain, commonly designated the Jurassic or the Cretaceous peneplain. This general conception is, however, to be modified to this extent, namely, that more or less extensive peneplanation followed by uplift took place previous to the completion of the Cretaceous peneplain. Details are, however, not necessary here. The Cretaceous peneplain is also called the Schooley peneplain from its excellent preservation on Schooley Mountains in Northwestern New Jersey. The southern part of the Appalachian Mountains and parts of the highlands region were not fully reduced, but projected above the general level. Upon this peneplain the great rivers draining the province, as mentioned on a previous page, probably assumed their present courses in adjustment to the rocks, the geologic structure, and the surface slopes.

Some time in the Cretaceous period the Appalachian Province was again bodily uplifted, more in some regions

than in others, so that the Cretaceous peneplain was warped from its approximately level surface. The uplift seems to have been greatest in eastern West Virginia whence the comparatively even surface sloped, though not uniformly, in all directions toward the margins of the province. The Cumberland Plateau, now 1,800 to 2,000 feet above sea level, is the most extensive, best preserved, and most obvious remnant of the uplifted Cretaceous peneplain.

If erosion had permanently been suspended in the region after the uplift of the Cretaceous peneplain, there would exist at the present day over most of the Appalachian Province a broadly warped and gently undulating surface with here and there hills upon it sloping away from an area of maximum elevation along the central part of the highlands in West Virginia. This maximum height was probably not less than 2,000 feet above sea level and may have been as much as 3,000 feet. Erosion, however, did not cease, and, just as the Cretaceous peneplain was formed over a large part of the Appalachian Province, so a second but less extensive peneplain was formed on the west side of the highland belt, along the Appalachian Valley, and along the Piedmont Plateau. While this general degradation was going on, the large rivers draining the province held the courses which they had acquired upon the comparatively level surface of the Cretaceous peneplain and as the country rose they wore out deep canyons in the Appalachian Plateaus, such as the New River canyon in West Virginia, and cut deep gashes across the ridges of the Appalachian Valley, such as those along Susquehanna River, north of Harrisburg, Pa. The locations of the rivers of the province are older than the present topography, and these streams are therefore called antecedent streams.

The highland belt was not reduced to the new peneplain level because another succession of uplifts took place, aggregating about 1,000 feet before there had been sufficient time for such reduction. The final uplift is supposed to have occurred in early Tertiary time after extensive peneplanation and the resulting peneplain is conveniently called the Tertiary peneplain. The general surface of the upland region in Ohio, etc., coincides with

this peneplain, the best and most obvious present area of which is the Highland Rim in Tennessee. The Highland Rim is 800 to 1,000 feet lower than the Cumberland Plateau, and an escarpmentof that height separates the two surfaces.

From the relation of these surfaces and the accepted principles underlying peneplaination, the following course of events in the Appalachian Plateaus is inferred. First, uplift to an unknown height at the time of the Appalachian revolution; second, a succession of periods of erosion and uplift, resulting in one or more peneplains, remnants of which are recognizable in various parts of the Appalachian Province. This series of events culminated finally in the reduction of the uplifted region nearly to sea level by the end of Jurassic time, forming the Jurassic or Cretaceous peneplain; third, uplift of the Cretaceous peneplain to about 500 feet above sea level in the Cumberland Plateau region; fourth, a period of erosion producing a partial peneplain 500 feet below the Cretaceous peneplain, a considerable area of which is now preserved in the highlands of Eastern Kentucky; fifth, a second uplift of about 500 feet; sixth, erosion of the Highland Rim, nearly to sea level and consequently about 1,000 feet below the level of the Cumberland Plateau; seventh, a succession of uplifts of the region aggregating about 1,000 feet, so that the Highland Rim and the rest of the extensive upland region in Kentucky, Ohio and Indiana stands at present 1,000 to 1,300 feet above sea level; eighth, the erosion of the present valleys in the upland and highland regions, producing the existing relief. The erosion of the highlands, however, has been in progress since the Cretaceous uplift, and to that fact in conjunction with the greater general altitude is due the extremes of relief and great ruggedness of that part of the Appalachian Province.

GLACIATION.—The last notable episode in the history of the Appalachian Province is the great glaciation of comparatively recent time. A period of relatively low temperature and great moisture prevailed for a long time and resulted in a great sheet of ice which radiated from Canada and spread over the Northern United States. The southern boundary of the ice sheet followed

an irregular line from western New York to southern Illinois, passing a few miles north of Louisville, Ky. The glacial border is shown on the map, Fig. 1. The ice age lasted a long time and there were several advances and retreats of the ice, the mapped southern border showing the line of maximum advance. The ice sheet in its advance transported great quantities of rock waste, mud, sand and bowlders, some of the latter from Canada. This waste in its present position is called glacial drift. On the melting of the ice, this drift was left on the surface in various forms. Valleys were filled up and the general effect was to make the surface smoother, except at the margins of the ice sheet where great quantities of material were in many cases piled up into irregular low ridges and hills. To this leveling effect is due the glaciated plains province to the northwest of the upland region. As a result of the valley filling, great changes were caused in the pre-existing drainage lines where the old channels were blocked up by glacial drift.

A change of this kind occurred at Louisville and is described on a succeeding page. Not only were deposits left in the areas covered by the ice, but also vast quantities of silt and gravel, borne in the body of the ice sheet or upon its surface, were washed out by the water produced by the melting of the ice and carried down the streams south of the glaciated area, overloading them so that much of the material was left in the valleys, filling them up to considerable depth. Such was the origin of the silt and gravel deposit about 100 feet in thickness upon which a large part of Louisville is built. These features so far as concerns Jefferson County will be more fully discussed in following pages of this report.

CHAPTER 3.

TOPOGRAPHY,

General Statement.—Having given the preceding general outline of the physiographic and geologic character and history of the Appalachian Province, a knowledge of which is a necessary preliminary to the understanding of these features of Jefferson County, the detailed description of the latter will now be taken up.

Physiographers recognize three stages of topographic development which are designated as youth, maturity, and old age. The stage of youth begins with the uplift of a region, which for the sake of illustration may be supposed to have been previously worn down nearly to a plain. This uplift results in increased descent of the streams, so that they have a higher velocity and greater eroding power than formerly. In consequence the streams attack the surface vigorously and wear out deep gorges with comparative rapidity. In time the streams reach a point in the down cutting at which their slopes are so nearly reduced to the level of their outlets that they can cut no deeper. In the meantime the main streams have extended their headwaters far back into the land and side streams have also cut deep side gorges extending also well back from the main gorges. The surface of the region at this stage is that of a broad level plain or plateau dissected by deep gorges or canyons.

The period during which the erosional work above outlined is accomplished is called the stage of youth. Succeeding this stage the work of the stream continues, the side walls of the gorges are gradually broken down and reduced to more or less gentle slopes, the streams branch out into all parts of the region and effectively drain it, falls and rapids are generally removed from the stream beds, which then have a fairly uniform slope, in which condition they are designated graded streams. The general surface is that of wide valleys, broadly rolling uplands, or of highlands with deep, steep sided val-

leys and many narrow ridge crests. This stage differs from that of youth in that it has perfectly graded streams which ramify to and drain effectively all parts of the region; in that the valley walls are more or less gentle slopes, and in that only a small part of the original uplifted surface is preserved on the summits of the region. This is the stage of maturity. By the still further continuance of erosion at a slower rate and the wearing down of the uplands beyond the stage of maturity, the general surface of the region is finally reduced to a gently undulating plain drained by sluggish and widely spaced streams. This is the stage of old age. This succession of events from uplift through youth, and maturity to old age is defined as a physiographic cycle.

It appears that the Kentucky region, of which Jefferson County is a part, is in the stage of topographic maturity of the present physiographic cycle, with the streams well graded and generally free from waterfalls, etc., and with broad valleys, gentle slopes and rounded uplands.

Relief.—As regards relief, Jefferson County falls into three distinctly characterized divisions, viz.: the knobs in the southwestern part of the county, the lowland southeast and southwest of Louisville, and the uplands in the eastern one-third of the county on both sides of Floyd's Fork. Of these, the Knobs, rising abruptly 250 to 500 feet above the wide level areas surrounding their base, are the most striking feature. They occupy a triangular area with northern apex in the vicinity of Jacobs Park, and southeast apex at South Park Hill, and southwest apex near Medora. This area is trenched near the middle by Pond Creek Valley and hollowed out on the east side by the low ground extending to Finley Hill and Fairdale. The surface of the Knobs is very rough, a condition due to minute dissection of the original flat upland. It is a typical example of ridge, spur, and knob topography. The ridge crests upon which rise low knobs are narrow and tortuous, and give off many long, narrow spurs separated by deep, narrow ravines. South Park Hill is an isolated ridge of striking aspect.

The height of the ridges and knobs is greatest near the south margin of the county, being there between 800 and 900 feet above sea level. A single point, about 2½ miles south-southwest of South Park station, and just within the county reaches the altitude of 900 feet, and is the highest point in the county. The knobs north of Pond Creek are not so high as those farther south, Kenwood Hill and Jacobs Park Hill at 740 feet being the highest.

As heretofore mentioned, the higher ridges and knobs in the southern part of the county probably approach near to the level of the Lexington Plain which formerly extended over this area.

By an inspection of the topographic map of the county it can be seen that the country east and northeast of the knobs is divisible into two rather distinctly contrasted parts which would be separated approximately by a line passing through Okolona and Bryan, and thence N. E. passing one-half mile east of the L. & N. railroad to the northeast boundary of the county. East of this line the county is noticeably more dissected and rougher than that on the west of it. Along the east side of Fern Creek there is a marked escarpment forming the eastern boundary of the smooth area. This escarpment is approximately the east edge of a dip slope on the Louisville limestone, a feature that is more fully described on a succeeding page of this report. The dip slope is very gentle and the escarpment abrupt, the two combined forming a cuesta.

The eastern, relatively rough area, is made up of rather broad ridges and spurs as a rule, with gentle slopes to the valley bottoms.

The country east of Floyds Fork as far north as the Louisville and Nashville railroad and that immediately west of Floyds Fork are more dissected and irregular than the rest of this division. The general altitude is 700 to 750 feet, being lower on the west. The highest point is 780 feet above sea level on the ridge 2½ miles northeast of Boston. The broad flats along Floyds Fork, as well as the high steep bluffs are features worthy of mention. These features are related, both being due to the lateral (sidewise) erosion of the stream at a time when the country probably stood somewhat lower than at present, in consequence of which the down-cutting activity of the stream was arrested and it expended its

energies in cutting away its walls and widening its valley floor. Although relatively smooth, the area occupying the central and western parts of the county is not level but slopes southwestward from an altitude of about 700 feet along the northeast boundary of the county to an altitude of about 450 feet near the base of the knobs and along the Ohio River. A strip of this surface about 3 miles wide east of the Ohio River northeast of Louisville is trenched to the depth of about 100 feet by the creeks tributary to the river.

The low, flat land 3 to 5 miles wide between the river and the knobs southwest of Louisville is an old glacial flood plain of the river, as is also the narrow strip of flat land along the river northeast of Louisville. Both these areas have been somewhat reduced and modified by recent erosion, the shallow valleys of Mill Creek and its tributaries being the most important of the modifications.

DRAINAGE.—The drainage of Jefferson County is by the Ohio River, which follows the northwest side of the county. The northwestern two-thirds of the county drains directly into the Ohio, the main streams being Harrods Creek, Little Goose Creek, and Goose Creek in the northern part of the county; the three branches of Beargrass Creek discharging at Louisville, Mill Creek, which, flowing southward roughly parallel to the river, and emptying near the southwest corner of the county, drains the alluvial flats southwest of Louisville, and Pond Creek which with Fern Creek drain the low central area of the county. Pond Creek bounds on the east the long, narrow southwest extension of the county. The eastern one-third of the county is drained by Floyds Fork and its tributaries, the principal of which are Long Run, Brush Run, and Cave Run on the east and Chenoweth and Cedar Creeks on the west. Floyds Fork flows southwest across the entire width of the county and empties into Salt River 6½ miles south-southeast of the Norton Hills. Salt River joins Ohio River just east of West Point, where it forms for a short distance the southwest boundary of the county.

The grade of the streams varies: Ohio River falls from 380 feet above sea level at the head of Sand Island, to 371 feet at the mouth of Salt River, or 9 feet in all, making the grade about 4½ inches per mile. From the head of Sand Island to a point just above the whirlpool in the stretch named on the map, "The Falls of the Ohio," a distance of 1 mile, the total fall is 20 feet, in the next mile above, the fall is about 6 feet, and from the dam at the head of the rapids to the county boundary on the northeast a distance of about 10 miles, the total fall seems to be about 3 or 4 feet, the rate being about the same as below the falls.

"FALLS OF THE OHIO."—The expression "Falls of the Ohio" is rather a misnomer. The only descents of the character of falls are an abrupt slope of 3 or 4 feet between the head of Rock Island and the foot of Goose Island, and a fall nearly south of the latter in the narrow channel between a low island and the mainland, both of which places are included in the western part of the area represented on the map as land just south of that part of the river called the Falls. Otherwise the feature is a rapids with a total descent of about 26 feet, partly on bare rock.

The upper part of the rapids, especially where crossed by the J. M. & I. (Pennsylvania) Railroad bridge is rocky.

The origin of the Falls is discussed under historical geology.

Floyds Fork falls 160 feet in crossing the county, a distance of about 18 miles, making a descent of 9 feet to the mile. Goose Creek, which may be taken as representative of the smaller creeks, has a total descent of 120 feet in the upper 3 miles of its course, 195 feet in the lower 6 miles, a fall respectively of 40 and 32½ feet per mile. Pond Creek falls 80 feet in 13 miles or 6 feet per mile.

In general the stream beds are uniformly graded. Falls and rapids are few, although it is common for the streams to have a rocky bed, which is, however, in the case of all the larger creeks, generally reduced to a fairly even slope.

The larger streams of the county carried a varying quantity of water during the summer season of 1914, which was a season of protracted drought, one of the most severe in the history of the region. In many of the

streams, however, and especially in those with rocky beds, the water had practically ceased to flow on the surface and was mainly accumulated as pools in depressions of the stream beds, such movement as existed being an underground seepage. Numbers of the streams, being fed by springs, maintained a fairly strong flow of water at least along much of their courses. There was, with exception of a few localities, sufficient water for stock, although, in those cases where the supply was limited to the stagnant pools in the stream beds, the quality was not of the best. It appears safe to conclude that in all ordinary seasons the streams carry an abundance of water for the ordinary demands of an agricultural and industrial community.

RELATION OF TOPOGRAPHY AND GEOLOGY TO MAN.—The geology and topography of a region have an important bearing upon its occupancy by man and upon the character of the people who occupy it. In the case of Kentucky the rich, level or gently rolling lands of the central part of the State, the typical Blue Grass region, invited the earliest settlements in the State. In later years, too, the fertility of the soil which depends upon the composition of the rocks, and the ease of tillage and of communication favored by the comparatively smooth topography have exercised a beneficent influence upon the material condition and culture of the inhabitants. The fertile, easily-cultivated soil has furnished the wealth of the people, while the navigable rivers first, and later the railroads, whose construction is favored by the topographic conditions of the region, have been important factors in the progress of the region in the comforts and arts of civilized life. To the differences in topographic and geologic features between the Blue Grass region and the highland region of Eastern Kentucky may be ascribed in a large measure the differences between their inhabitants in respect to material and intellectual conditions.

CLIMATE.—Louisville is located in latitude 38°–15′ N., and longitude 85°–45′ W. Its mean annual temperature for the period of 31 years, 1873 to 1903 is 57°, the total precipitation for the driest year in that period is 29.6 inches, for the wettest year 56.6 inches, and the mean

annual precipitation 44.5 inches; the average annual depth of snowfall in 19 years was 14.4 inches; the average amount of possible sunshine for 10 years was 58 per cent. These facts of climate are exhibited in the following table taken from Bulletin 2, Climatology of the United States, U. S. Weather Bureau 1906.

Jefferson County climatological data for year 1873 to 1903, compiled from records of Louisville Weather Station. Extract from Climatology of the U. S. Weather Bureau, 1906.

MONTHLY, SEASONAL AND ANNUAL MEANS.

MONTH.	Temperature: Mean.	Temperature: Mean of the maxima.	Temperature: Absolute maximum.	Temperature: Mean of the minima.	Temperature: Absolute minimum.	Temperature: Highest monthly mean	Temperature: Lowest monthly mean.	Precipitation: Mean.	Precipitation: Number of days with 0.01 or more.	Precipitation: Total amount for the driest year.	Precipitation: Total amount for the wettest year.	Precipitation: Snow: Average depth.	Precipitation: Snow: Greatest depth in 24 hours.	Mean Humidity: Relative, 8 a. m.	Mean Humidity: Absolute, 8 a. m.	Mean Humidity: Relative, 8 p. m.	Mean Humidity: Absolute, 8 p. m.	Total Sunshine: Average hours.	Total Sunshine: Percentage of possible	Direction of prevailing wind.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.	Degrees F.	Degrees F.	Degrees F.	Inches		Inches	Inches	Inches	Inches	Per ct.	Grs.	Per ct.	Grs.			
December	38	45	74	31	—7	52	28	3.7	11	4.6	2.0	2.4	10.4	76	1.80	66	1.95	4	42	SW.
January	35	42	72	27	—20	50	25	3.9	13	1.0	6.3	3.7	5.5	72	1.46	63	1.61	4	43	SW.
February	37	45	78	29	—14	48	27	3.9	11	1.2	9.7	4.5	6.0	72	1.52	63	1.73	5	46	S.
Winter mean	37	44		29				11.5	35	6.8	18.0	10.6		73	1.59	64	1.76	4	44	SW.
March	45	54	86	36	3	53	40	4.3	13	3.6	5.8	3.2	12.3	75	2.14	63	2.31	6	49	SW.
April	56	66	91	47	21	65	49	4.0	12	2.5	2.2	0.2	1.7	70	2.96	55	3.16	8	57	S.
May	67	76	94	57	33	73	62	3.8	12	2.4	7.5	Tr.	1.0	72	4.28	58	4.63	9	63	S.
Spring mean	56	65		47				12.1	37	8.5	15.5	3.4		72	3.13	59	3.37	8	56	S.
June	75	84	100	66	44	79	70	4.3	12	4.1	5.2	0.0	0.0	74	5.72	59	6.06	10	67	S.
July	79	88	107	69	54	84	74	3.8	10	2.8	4.6	0.0	0.0	73	6.41	57	6.43	10	70	SW.
August	77	86	105	67	50	82	73	3.5	8	2.9	5.4	0.0	0.0	76	6.06	59	6.25	10	73	N.
Summer mean	77	86		67				11.6	30	9.8	15.2	0.0		74	6.06	58	6.25	10	70	
September	70	80	102	60	36	77	65	2.7	8	2.8	3.6	0.0	0.0	77	4.89	58	5.26	9	70	N.
October	59	69	91	49	26	66	53	2.6	8	0.5	1.6	Tr.	Tr.	77	3.25	57	3.50	8	71	N.
November	46	54	79	38	4	54	37	4.0	10	1.2	2.7	0.4	2.6	76	2.24	64	2.43	5	50	N.
Fall mean	58	68		49				9.3	26	4.5	7.9	0.4		77	3.46	60	3.73	7	64	N.
Annual mean	57	66	107	48				44.5	128	29.6	56.6	14.4		74	3.56	60	3.78	7	58	S.

First killing frost in Autumn .... September 24
First killing frost in Autumn (average date) .... October 29

Last killing frost in Spring .... May 14
Last killing frost in Spring (average date) .... April 6

CULTURE.—Jefferson County is thickly populated, Louisville having about 240,000 inhabitants and the rest of the county over 40,000. Anchorage, Middletown and Jeffersontown are the principal towns outside of Louisville.

Except for the steep slopes in the knob region and on the east side of the county, the area of the latter is mostly cleared and in tillage or pasture. The county has excellent roads. Main roads or turnpikes radiate in all directions from Louisville to and beyond the county borders. These, as well as many of the intermediate and cross roads are macadamized and provided with substantial bridges. The more recently constructed of the latter are of concrete.

Like the turnpikes, electric railroads radiate from Louisville in all directions and to such distances as to afford very convenient means of transportation of passengers and freight. Orell, Okolona, Fern Creek, Jeffersontown, and Prospect are termini of such lines. Besides these are lines through Middletown to Shelbyville and through Anchorage to Lagrange, both east of the county, and to New Albany, Indianapolis and Charlestown in Indiana.

Likewise steam railroads center in Louisville from all directions. The Southern and Monon routes from the northwest, the Pennsylvania and Baltimore and Ohio from the northeast, the Louisville and Nashville Railroad from Cincinnati and Nashville, the Louisville and Nashville, Chesapeake and Ohio, and Southern from Lexington, and the Louisville, Henderson and St. Louis, and the Illinois Central from the southwest.

In addition to these means of communication and transportation the Ohio River affords a cheap outlet to both the East and West, an outlet which will be greatly improved by the completion of the enlargement of the Louisville Canal around the "Falls."

CHAPTER 4.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

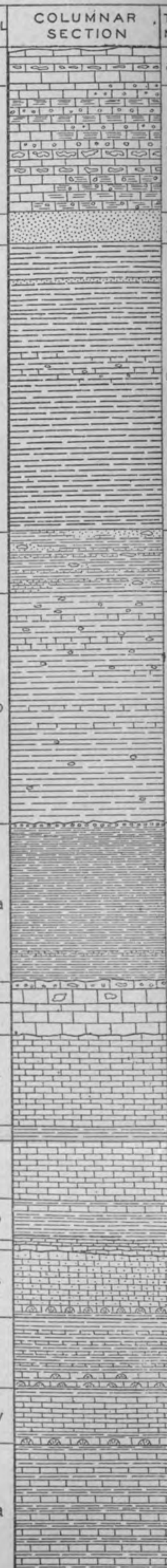
The known stratified rocks of the earth's crust are, according to age and superposition, divided and subdivided into units to which such names as system, series, group, formation and member are applied, according to rank. Likewise the times corresponding to the various rock units are called eras, periods and epochs. The major divisions as recognized by the U. S. Geological Survey are shown in the following table.

Table Showing Major Divisions of Strata and Time.

TIME			ROCKS.	
Era.	Period.	Epoch.	System.	Series.
Cenozoic. (Age of mammals.)	Quaternary.	Recent. Pleistocene.	Quaternary.	Recent. Pleistocene.
	Tertiary.	Pliocene. Miocene. Oligocene. Eocene.	Tertiary.	Pliocene. Miocene. Oligocene. Eocene.
Mezozoic. (Middle life.) (Age of reptiles.)	Cretaceous. Jurassic. Triassic.		Cretaceous. Jurassic. Triassic	
Paleozoic. (Ancient life.)	Carboniferous. Devonian. Silurian. Ordovician. Cambrian.		Carboniferous. Devonian. Silurian. Ordovician. Cambrian.	Rocks of Jefferson County.
Proterozoic.	Algonkian.		Algonkian.	
	Archean.		Archean.	

Various changes in arrangement shown in the above table have been introduced by individual writers on stratigraphic geology. Such changes are at present under discussion and some of them will undoubtedly become established in time. The table as it stands, however, sets forth the age, succession, subdivision and arrangement of the stratified rocks entering into the composition of the earth's crust, and the general sequence of events in its history so that the general reader may have a notion of the geologic setting and a perspective of the rocks of Jefferson County.

In addition to the divisions shown in the above table, which are world-wide in their extent, the series are subdivided into groups, formations, and members, which are only local or regional in extent. Of these subdivisions the formation is the most important. A formation is made up mainly of one kind of rock, as shale, sandstone, or limestone, or of a uniformly varied series of beds such as an alternation of thin layers of shale and sandstone or of shale and limestone.



System	Series	Group	Names of formations	Symbol	Thickness	Names of minor divisions	General character of formations.
CARBONIFEROUS	MISSISSIPPIAN	MERAMEC	Spergen ("Salem") limestone	Cs	25' ±		Coarse grained, light gray, thick bedded, slightly cherty, fossiliferous limestone.
			Warsaw ("Harrodsburg") limestone	Cw	60'-80'		Varies with the localty. Siliceous and argillaceous limestone with abundant geodes; coarse crinoidal limestone; solid chert layers up to one foot thick, full of sponge spicules; layers of dark gray shale. Chert and crinoidal layers fossiliferous.
		OSAGE (KNOBSTONE)	Holtsclaw sandstone	Ch	20' ±		Fine grained, loosely cemented, soft sandstone grading into Rosewood shale below. Syringothyris, Spirifera, Orthotetes.
			Rosewood shale	Cr	190'		Bluish shale, weathering gray. Splits with uneven surface. A few sandy layers, thin limestone lenses and small iron nodules. In the upper half it is full of curly markings suggesting worm tracks. Other fossils abundant a little above the middle associated with the limestone lenses and iron nodules.
			Kenwood sandstone	Ck	40'		Varies with the locality. In most of the area, thin, even layered, fine grained, greenish sandstone in bluish shale. Locally, as on top of Button Mould Knob, one mile south of Norton Hills, a massive sandstone. Iron concretions (turtle stones) in both sandstone and shale.
			New Providence shale	Cnp	140'-160'		Mainly soft, green or bluish clay shale. Full of iron nodules in the upper half. In places many thin layers of coarse crinoidal limestone highly inpregnated with iron on the outcrop. These limestone layers highly fossiliferous at the north end of Kenwood Hill and in Button Mould Knob.
DEVONIAN (CARBONIFEROUS?)	UPPER		New Albany shale	Dna	100' ±		Black, carbonaceous, fissile shale. Thin, fine grained, calcareous sandstone layers near the bottom. Spore cases, Protosalvinia (sporangites) abundant. Pseudobomia (calamites) and fish bones associated with the sandstone layers 10 to 15 feet above the bottom. Lingula and conoducts rare throughout. Schizobolus rare and confined to the bottom six inches so far as found. Phosphatic nodules at top. Unconformity between New Albany and New Providence shales.
	MIDDLE		Sellersburg ls.	Ds	4'-6' 0'-16'	Beechwood ls. Silvercreek ls.	Coarse grained, light gray, highly crinoidal limestone. (Dsb.) Fine grained, dark gray, cherty, fossiliferous limestone. Dss. Formerly utilized for cement rock.
			Jeffersonville limestone	Dj	0'-30'		Coarse grained, dark gray, thick bedded limestone. Crowded with fossil corals and other fossils.
SILURIAN			Louisville limestone	Slv	45'-100'		Thick bedded, medium grained limestone. Bluish gray. Cherty in upper part. Highly fossiliferous in the upper 5 to 8 feet and moderately fossiliferous in the lower 20 feet. Important quarry rock, building stone and road metal. Unconformity between Louisville and Jeffersonville limestones representing Oriskany, Helderburg, and Cayuga times and, in New York and Pennsylvania, representing 2,300 feet of strata, not present in Jefferson County. Unconformity at base between Louisville limestone and Waldron shale.
			Waldron shale	Sw	10'		Bluish, calcareous and magnesian shale. Fossils very scarce.
			Laurel dolomite	Sl	40'		Medium thick bedded, rather fine grained, bluish gray, highly magnesian limestone. Fossils very scarce. Important quarry rock, building stone and road metal.
			Osgood formation	So	30' ±	Upper shale 2½' Upper limestone 5'-8' Lower shale 15-20' Lower limestone 2'	Blue, calcareous shales and medium grained limestones. Upper shale with many calcite inclusions up to several inches in diameter. Lower shale with a bed of red shale near the bottom.
			Brassfield ls.	Sb			Coarse, crystalline, yellow, mottled, fossiliferous limestone. Unconformity at top and bottom (See text of report.)
ORDOVICIAN (SILURIAN?)		RICHMOND	Saluda limestone	Os	30'-35'	Hitz limestone, 0-3' Columnaria and Tetradium zones	Blue fine grained limestone. Ostracods, pelecypods and gastropods abundant. Below Hitz limestone member, thick bedded, fine grained, highly magnesian, sandy limestone. Color banded on weathering, gray when fresh. Fossils very scarce. At bottom coarse, lumpy mud rock with pure limestone layers with Columnaria, Tetradium, Ostracods and Bryozoa.
			Liberty formation	Ol	35'-50'	Columnaria, Calapoecia and Beatrecia zones	Thin limestone interbedded in blue clay shale. Highly fossiliferous.
			Waynesville limestone	Ow	40'	Columnaria and Tetradium zones	Mainly thick bedded limestone weathering gray. 10 feet of greenish shale with abundant globular bryozoan (Cyphotrypa clarksvillensis) below overlying 4 feet of gray, argillaceous limestone with abundant Columnaria, Tetradium and Gastropods. Fossils scarce in main body of limestone.
			Arnheim formation	Oa	80'-100'		Thin, blue, granular, irregularly surfaced limestone interbedded in blue clay shale. Fossils very abundant, especially Platystrophia and various species of Bryozoa.

Generalized section of rocks in Jefferson County, Kentucky.
Scale: 1 inch=100 feet.

FORMATIONS.

lightly cherty, fossiliferous lime-

llaceous limestone with abundant
ayers up to one foot thick, full of
hert and crinoidal layers fossili-

one grading into Rosewood shale

uneven surface. A few sandy
odules. In the upper half it is
Other fossils abundant a little
nses and iron nodules.

DETAILED DESCRIPTION OF STRATA.

MAIN DIVISIONS AND ORDER OF TREATMENT.—The rocks known in Jefferson County are for convenience artificially divided into two main divisions, those well known from surface outcrops and those not so well known, that have been penetrated by deep wells and are inferred from their outcrops between Jefferson County and High Bridge, Kentucky, and other regions to the east of the county to be present beneath this county. The rocks not exposed and those exposed will be treated under separate heads; the former will be first described from the top downward, and the latter will be described last in the order of their deposition from the bottom upward. In his reading the reader should consult the columnar section, Plate 65, on a succeeding page.

As a general thing a formation has fairly definite and recognizable upper and lower limits. In some cases two or more formations may be taken together as a group or series. Likewise in many cases a small part of a formation of distinctive character is treated as a member.

LENGTH OF GEOLOGIC TIME.—Before proceeding to the description of the rocks of the county a brief statement of the estimate of geologic time will be of interest. By various methods geologists have attempted to reach an approximate determination of the time that has elapsed since the oldest stratified rocks known were deposited. The principal method perhaps is this: The best calculation possible is made of the thickness of the stratified rocks and this thickness is divided by the average rate of deposition as determined at the present time by observing the amount of sediment discharged by the larger rivers of the earth. There are other methods but this is the most important; the results are of course only approximate and vary according to the fundamental data accepted for use in the computations. The results reached in the greater number of estimates are, however, fairly accordant and vary between seventy-five and one hundred million years. It is also estimated that Paleozoic time was four times as long as Mesozoic and twelve times as long as Cenozoic; also that the Cambrian, Ordovician and Silurian periods were together a little over twice as long as the combined length of the Devonian and Car-

boniferous. On these assumptions it works out, taking the total time as one hundred million years, that the end of the Silurian was about fifty million years ago. In other words the Louisville limestone, which was deposited before the end of Silurian time, is over fifty million years old, and the corals that lived so profusely in Devonian time at the "Falls" and whose remains are still preserved in the rocks forming the bed of the river may have made a miniature, brightly tinted, submarine forest at the "Falls" as much as forty-five million years ago.

While these figures of age can not be accepted as anywhere nearly exact, they still contain enough of truth to demonstrate that geologic processes have extended over an almost incomprehensible length of time when thought of in terms of years. A few million years one way or the other does not disturb that grand conception. The earth is not the creation of a few days but a growth, a product of operations that have continued for thousands of centuries.

ROCKS NOT EXPOSED AT THE SURFACE.

SOURCES OF INFORMATION.—Direct knowledge of the rocks underlying a region but not outcropping on the surface is derived from deep wells drilled in prospecting for oil, gas or water. In the absence of deep wells or of a complete record of the strata penetrated if wells have been drilled, as is the case in Jefferson County, inferences of more or less validity may be drawn from the rocks outcropping in adjacent regions and known from the geologic structure to dip beneath a given area. Thus the character of the strata underlying Jefferson County to the depth of 1,500 feet below any rocks outcropping in the area can be in part inferred according to the last method and in part directly affirmed from the first.

DESCRIPTION OF THE ROCKS NOT EXPOSED.—At least three wells have been drilled in Jefferson County that have reached the sandstone or sandy limestone supposed to be the St. Peter sandstone* of the Mississippi Valley. These wells are the St. Patrick well on Third Avenue, Louisville; the Dupont well near Tenth and Rowan Streets, and the Fisherville well located about two miles west of Fisherville. The depth of these wells is 1,952, 2,080, and 1,525 feet respectively. Unfortunately no records of these wells are available and therefore very little information concerning the rocks penetrated is to be had. The only definite statement concerning the rocks is that the St. Patrick well penetrated a white sandstone† at something over 1,900 feet in depth. This

*The formation here and on succeeding pages correlated as supposedly "St. Peter Sandstone" may not be that sandstone. It is, in position, about where the St. Peter would be found, but differs in composition (being a magnesian limestone carrying a small percentage of sand) and is of much greater thickness than any known exposure of the St. Peter, wells having penetrated it to a depth of 700 feet without going through it and without showing any decided change in the character of the formation. It has heretofore been called the "Calciferous" in the reports of the Kentucky Geological Survey. It is possible that the St. Peter limestone has thinned out and disappeared before getting this far east and that this is a lower formation. J. B. H.

†This is a sandstone only in appearance. An analysis of this formation as found in a recently drilled well at Lebanon Junction gave:

	Per Cent.
Calcium carbonate	55.9
Magnesium carbonate	38.2
Sand	4.0
Undetermined	1.9

It is probably the Lower Magnesian Limestone. J. B. H.

white sandstone yields water containing large quantities of common salt and of sulphur compounds (sulphur-saline water). In its reported composition and in the character of its water the sandstone seems to agree with the St. Peter. The St. Patrick well starts about the middle of the black New Albany shale, at a geologic horizon which is about 450 feet above the bottom of the Arnheim formation, the bottom of the Arnheim being the lowest horizon exposed in outcrop in the county. The bottom of the well is therefore about 1,500 feet below the bottom of the Arnheim. The Dupont well starts at about the same horizon as the St. Patrick well and its bottom is therefore about 1,628 feet below the bottom of the Arnheim formation since the Dupont well is 128 feet deeper than the St. Patrick well. The Fisherville well is 1,525 feet deep. It starts near the middle of the Arnheim and its bottom is therefore near the same stratigraphic level or horizon as the other two wells. All these wells yield the same character of water. The character of the water and the stratigraphic position both indicate therefore that the water bearing stratum is the same in all.

It is not stated how far the supposed St. Peter sandstone was penetrated in the St. Patrick well, but taking 27 feet as a fair estimate, the top of the sandstone would be 1,925 feet deep and the space between the bottom of the Arnheim, which is about 450 feet below the well head, and the top of the sandstone is 1,475 feet. The question is what kind of rocks fill up this space. The answer must be inferred from the outcrops east of this county where the strata penetrated in the wells, rising eastward, nearly all come to the surface, as in the region between Shelbyville and High Bridge, Ky., and along Ohio River between Madison, Ind., and Cincinnati. In these sections immediately underlying the Arnheim is about 150 feet of alternating thin limestone layers and blue, lumpy, calcareous shale similar in character to that of the Arnheim. This is the Maysville group, which forms the upper half of the hills upon which Cincinnati is built. Below the Maysville group is a predominantly shale series interspersed with a good many thin and rather even limestone layers. This is the Eden group

which is 250 feet thick at Vevay, Ind.,* that place being possibly the nearest point to this region at which its full thickness has been determined and it can be fairly considered to be 250 feet thick under Jefferson County. The Maysville and Eden thus aggregate 400 feet in thickness. Deducting this thickness from the 1,475 feet between the Arnheim and supposed St. Peter leaves 1,075 feet to be accounted for. There is abundant evidence from surrounding regions, such as Cincinnati, Lexington, Wayne County, Ky., Southern Indiana, and Illinois, that this space is occupied by compact limestone of Mohawkian (Trenton, Black River, etc.), and Chazy (Stones River) ages. According to reports, however, there is great variation in the thickness of these limestones in different regions. At Cincinnati they are, according to Fuller,† 750 feet thick; in the Lexington, Ky., region, they are, according to Matson,‡ 864 feet thick. At North Vernon, Indiana, according to Leverett,§ the St. Peter is 1,400 feet deep in a well which starts about the top of the Sellersburg limestone; if the formations there down to the bottom of the Eden are as thick as supposed to be at Louisville, viz., 800 feet, the limestones between the Eden and the St. Peter at North Vernon are 600 feet thick. According to Munn,|| in the vicinity of Steubenville, Wayne County, Ky., the equivalent limestones are about 1,500 feet thick.**

It follows from the statements above either that the distance between the Eden group and the supposed St. Peter varies by over 900 feet between North Vernon, Ind., and Steubenville, Wayne County, Ky., or that the sandstone identified in the various wells as St. Peter is

*Cummings, E. R., The Stratigraphy and Paleontology of the Cincinnatian Series of Indiana: Indiana Dept. Geol. and Nat. Resource, 3d Ann Rept., pp. 605-1188, 1908.

†Fuller, M. L., Underground Waters of Southwestern Ohio; Water Supply Paper U. S. Geol. Survey 259, p. 23, 1912.

‡Matson, G. C., Water Resources of the Blue Grass Region, Ky.: Water Supply Paper, U. S. Geol. Survey No. 233, pp. 16 and 17, 1909.

§Leverett, Frank, Water Resources of Indiana and Ohio: U. S. Geol. Survey Eighteenth Annual Rept., pt. 4, p. 426, 1897.

||Munn, M. J., Oil and Gas Fields in Wayne and McCreary Counties, Kentucky: U. S. Geol. Survey Bull. 579, p. 16, 1914.

**This thickness is too great. In Wayne County it is about 1,500 feet from the base of the Devonian down to the formation here called St. Peter. The thicknesses given for Lexington and Cincinnati are too small and the variation between North Vernon and Wayne County (900 feet) is much too great. At Frankfort the interval is a little over 1,000 feet from the base of the Eden to the top of the sandstone here called St. Peter. J. B. H.

not the same bed in all the wells. It is not possible to decide which supposition is true with the data at present in hand.

Matson† describes the supposed St. Peter as a greenish or white sandstone or sandy limestone, the change to which from the overlying dark limestone being very distinct. He states furthermore that beginning with the St. Peter, wells have penetrated 500 to 700 feet of fine grained siliceous limestone correlated by the Kentucky geologists with the Beekmantown limestone (Calciferous sandstone) which underlies the Chazy in New York and the Appalachian Valley. It is possible that more than usually sandy streaks lying at different levels in this mass have been mistaken at different localities for the St. Peter in interpreting well logs.

It is fairly certain, nevertheless, that the following section, given partly for the benefit of persons contemplating drilling deep wells for any purpose, is approximately correct. The section begins at the bottom of the Arnheim formation and is what would probably be encountered in a well drilled on Floyds Fork one mile north of Seatonville where the creek bed is near the bottom of the Arnheim.

Rocks Below the Bottom of the Arnheim Formation, Which Would Probably Be Encountered If a Well Should Be Drilled on Floyds Fork 1 Mile North of Seatonville, Where the Stream Flows About at the Bottom of the Arnheim.

	Feet.
Maysville group:	
1. Shale, blue, coarse, lumpy, calcareous, with many rough, thin limestone layers	150*
Eden group:	
2. Shale aluminous and calcareous, predominantly soft, fairly fissile, with a good many thin even limestone layers	250*

†Loc. cit., p. 18.

*More or less.

Strata of Trenton, Black River ("Birdseye") and Stones River (Chazy) age:	
3. Limestone compact, thick and thin bedded, with shale partings in some zones	1,075*
St. Peter(?) Sandstone and beds of Beekmantown age. ("Lower Magnesian, Calciferous."):	
4. Sandstone, white or greenish (at top), and siliceous limestone or dolomite	1,000*†
Total	2,475*

In a well at Findlay, Ohio, about 250 miles northeast of Louisville, the distance from the top of the supposed St. Peter to the underlying granite is 876 feet, the rocks being largely sandstone, but including several beds of magnesian limestone. While the conditions are not necessarily the same in Jefferson County as at Findlay, an approximate correspondence seems most probable, and the estimate of 1,000 feet at Louisville from the top of the supposed St. Peter down to granite seems about as reasonable a guess as can be made. At Louisville 450 feet should be added to the total depth of the above section on Floyds Fork for the thickness of the rocks present at the former locality above the bottom of the Arnheim, including west of Bear Grass Creek, 100 feet of alluvium and gravel. According to these estimates, if they are correct, the total depth at Louisville to the granite is 2,975 feet. It is distinctly to be understood, however, that this is a matter of speculation as both the actual thickness of the supposed St. Peter and the possible presence of sandstone of Potsdam age between it and the granite, are unknown quantities.

*More or less.

†Actual thickness unknown.

ROCKS EXPOSED AT THE SURFACE.

GENERAL STATEMENT.—The rocks exposed at the surface in Jefferson County belong to the Ordovician, Silurian, Devonian and Carboniferous systems. The sequence, character and names of the subdivisions of the rock strata are exhibited in the columnar section, Plate 65. The following description proceeds in the order of deposition, beginning with the oldest, the Ordovician system.

ORDOVICIAN SYSTEM.

The exposed formations in this county which are generally referred to the Ordovician system are enumerated in the following table. They all belong to the Richmond group. The correctness of the reference of this group to the Ordovician is questioned by some geologists, notably E. O. Ulrich. Ulrich assigns the group to the Silurian system and the present writer is inclined to agree with him.

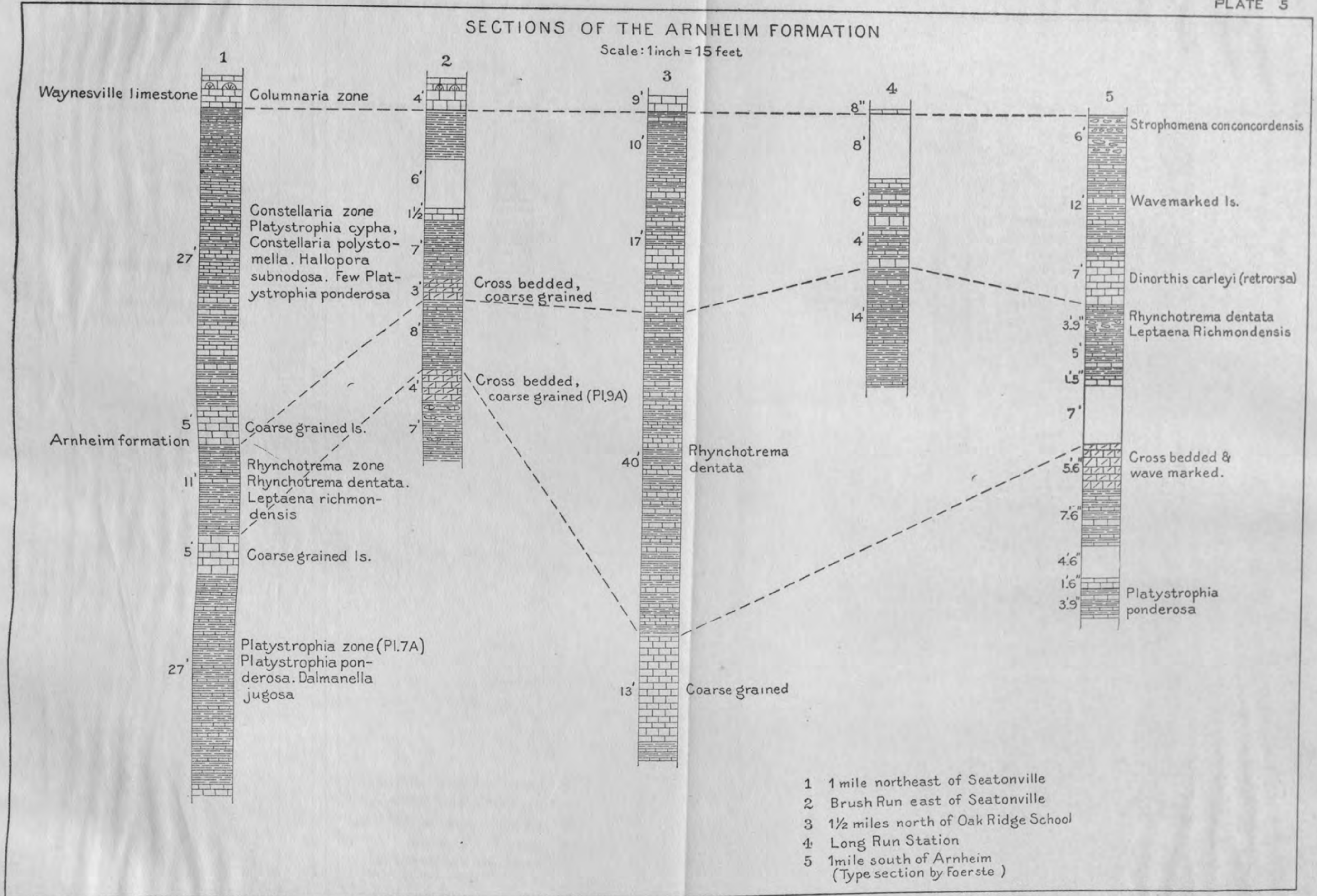
Pending further discussion, however, it has been thought best to adhere to the established usage for the present. The question is further discussed on a succeeding page.

Table Showing Names and Arrangement of Ordovician Formations.

Unconformity.
Richmond group.
  Saluda limestone.
    Hitz limestone member (at top).
  Liberty formation.
  Waynesville limestone.
  Arnheim formation.
Unconformity.
Maysville group.
  (Underlies county but does not outcrop within its limits. See description of rocks not exposed.)

RICHMOND GROUP.

The Richmond group is named from Richmond, Ind., where its upper strata are well exposed. It is composed of limestone and calcareous shale and is subdivided into the following formations named in ascending order:


SECTIONS OF THE ARNHEIM FORMATION
Scale: 1 inch = 15 feet
1
2
3
4
5
Waynesville limestone
Columnaria zone
27'
Constellaria zone Platystrophia cypha, Constellaria polystomella. Hallopora subnodosa. Few Platystrophia ponderosa
5'
Coarse grained ls.
Arnheim formation
11'
Rhynchotrema zone Rhynchotrema dentata. Leptaena richmondensis
5'
Coarse grained ls.
27'
Platystrophia zone (Pl.7A) Platystrophia ponderosa. Dalmanella jugosa
4'
6'
1½'
7'
3'
Cross bedded, coarse grained
8'
4'
Cross bedded, coarse grained (Pl.9A)
7'
9'
10'
17'
40'
Rhynchotrema dentata
13'
Coarse grained
8"
8'
6'
4'
14'
Strophomena concordensis
6'
12'
Wavemarked ls.
7'
Dinorthis carleyi (retrorsa)
3'9"
Rhynchotrema dentata Leptaena Richmondensis
5'
1'5"
7'
5'6"
Cross bedded & wave marked.
7'6"
4'6"
1'6"
3'9"
Platystrophia ponderosa
1 1 mile northeast of Seatonville
2 Brush Run east of Seatonville
3 1½ miles north of Oak Ridge School
4 Long Run Station
5 1mile south of Arnheim (Type section by Foerste)

Arnheim formation, Waynesville limestone, Liberty formation, and Saluda limestone. The description of these formations follows:

ARNHEIM FORMATION.

NAME AND DEFINITION.—The Arnheim formation was named by Foerste* from the village of Arnheim in Brown County, Ohio. Foerste placed the upper limit of the Arnheim at the top of a "lumpy" or "nodular" limestone carrying *Strophomena concordensis*, and its lower limit at the top of Nickles' Mount Auburn beds of the Maysville group. (See type section at Arnheim, Plate 5, Section 5.) In Jefferson County the writer places the upper limit of the Arnheim at the bottom of a persistent 4-foot bed of drab, argillaceous limestone everywhere carrying *Columnaria alveolata*. Lithologically this limestone is clearly to be included with the Waynesville limestone, immediately overlying the Arnheim. The lower limit of the Arnheim is probably determined by an unconformity in this county, as it is at Sulphur in Henry County 20 miles northeast of the county and at Madison, Indiana, where the Arnheim succeeds the *Monticulipora molesta* zone (Bellevue beds of Nickles), of the Maysville group, the Mount Auburn and Corryville beds of Nickles, the upper two divisions of the Maysville, being absent. The bottom of the Arnheim probably is not exposed in this county, however, for the lowest exposed beds have not yielded fossils of Maysville age, but rather fossils allying them with the Arnheim.

DISTRIBUTION.—The Arnheim being the lowest formation stratigraphically that is exposed in the county, outcrops only on Floyds Fork and its tributaries, and there does not extend very high above stream level. On Floyds Fork its top comes to the surface one-half mile south of the Electric railroad bridge west of New Eastwood, and the formation outcrops along the fork to where it crosses the southern boundary of the county. The Arnheim outcrops along all the larger streams east of Floyds Fork to the east boundary of the county, and such streams as Long Run, Brush Run east of Fisherville and Cane Run

*Foerste, A. F., Science, new ser., vol. 22, pp. 149-152, 1905.

have their beds upon the bare rock of the formation, and for the greater part of their length upon one or another of the limestone layers. On the west side of Floyds Fork, the formation, owing to its westward dip, and to the westward rise of the stream beds, outcrops but a short distance up the streams such as Chenoweth and Poke Lick Creeks. Various parts of the formation are well exposed along these streams, which slowly descend through the beds toward their mouths. About the whole thickness of the formation is exposed in a bluff on the east side of Floyds Fork about 1¼ miles northeast of Seatonsville. At this place the lower beds are completely exposed while the upper are somewhat obscured by slumped material and further obscured in the photograph by bushes. A view of this exposure is shown in Plate 2.

THICKNESS.—Since the bottom of the Arnheim is not exposed in the county, its thickness could not be determined. As shown in section No. 3, Plate 5, its thickness is not less than 85 feet. Sections at Sulphur, Ky., 20 miles northeast of Jefferson County and at Madison, Indiana, some 50 miles northeast, do not indicate more than 100 feet and it is believed that it does not exceed that thickness.

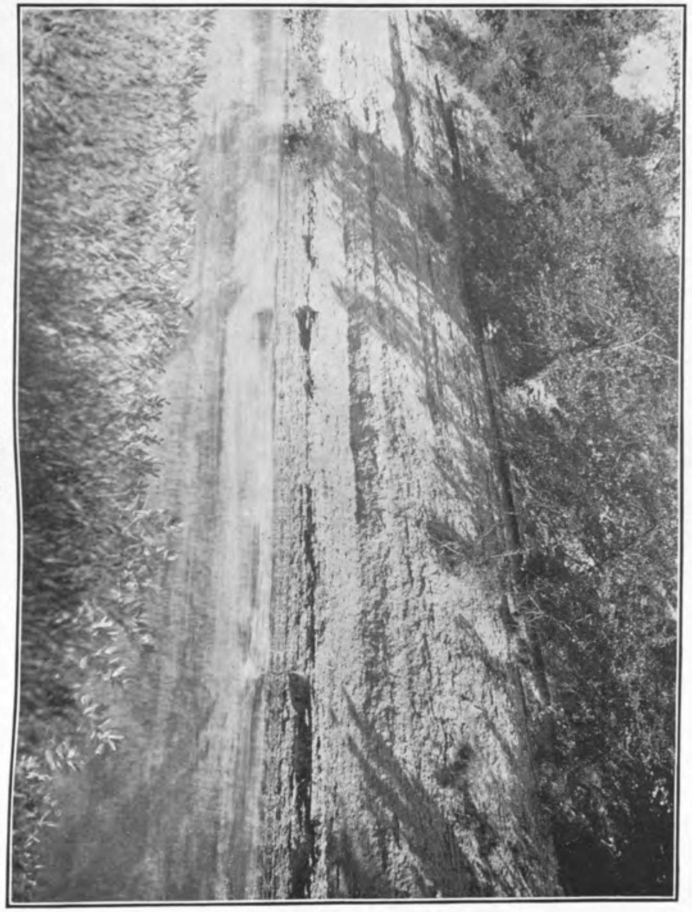


Plate 2.

View of the Platystrophia ponderosa zone composing the lower part of the Arnheim formation. Bluff on the east side of Floyds Fork 1¼ miles northeast of Seatonsville. The overhanging layer at edge of brush is the same layer as the lower crossbedded limestone well exposed on Brush Run 1 mile east of Seatonville and shown in Plate 4. Looking east.

CHARACTER.—The type section of the Arnheim is given by Foerste* as follows:

Type Section of the Arnheim Formation, Straight Creek, 1 Mile South of Arnheim, Brown County, Ohio.

		Ft.	In.
16.	Strophomena concordensis near top of blue, nodular clay rock	6	
15.	Limestone interbedded with much clay. Strongly wave-marked limestone	12	
14.	Limestone interbedded with clay	7	
	Dinorthis carleyi rare.		
13.	Thin limestone and clay with Leptaena richmondensis and Rhynchotrema dentata		6
12.	Limestone with clay, Leptaena richmondensis abundant		9
11.	Clay with layers of nodules	2	4
10.	Thin limestone with Leptaena richmondensis abundant		2
9.	Limestone and clay	5	
8.	Platystrophia ponderosa abundant in limestone		8
7.	Dalmanella jugosa var. abundant, largest specimens 22 millimeters wide associated with Platystrophia ponderosa rather few		9
6.	Poorly exposed	7	
5.	Coarse grained, cross bedded limestone with wave-marked layer 5 inches above the base	5	6
4.	Limestone and clay interbedded	7	6
3.	Rafinesquina very abundant	4	6
2.	Limestone with bryozoans very abundant	1	6
	Total Arnheim	54	9
1.	Mount Auburn beds of Nickles, top consisting of clayey limestone with Platystrophia ponderosa rather abundant	3	9

This section shows that the formation at the type locality is composed of alternating layers of clay (shale) and limestone of varying thickness. It contains also a small assemblage of fossils that have been found to be peculiar to the upper part of the Arnheim throughout a wide territory. These are *Platystrophia ponderosa*, *Leptaena richmondensis*, *Rhynchotrema dentata* and *Dinorthis carleyi*. (See Plate 8, for illustrations of these fossils). The association of any one of the last three named fossils with *Platystrophia ponderosa* is regarded by

*Foerste, A. F., Ohio Naturalist, vol. 12, No. 3, p. 442.

Foerste as a sure criterion for recognizing the Arnheim. He has followed the latter by its lithology and fossils from its type locality along the eastern side and southern end of the Cincinnati dome through Lewis, Fleming, Bath, Montgomery, Clark, Madison, Garrard, Lincoln, Boyle, Marion, Nelson and Bullitt Counties into Jefferson County and demonstrated its continuity between the two regions and its presence in Jefferson County as identified in this report.

Foerste recognized two divisions of the Arnheim, an upper division characterized by the fossils mentioned above, which he called the Oregonia division, and a lower division containing in places cross bedding, ripple marks, and other phenomena (see Plate 6), which he named the Sunset division, and which he included in the Arnheim, partly at least because they seemed to represent conditions attendant upon the movements connected with the unconformity at base of the Arnheim. It is to be supposed that in areas that had been elevated above water, perhaps but slightly, during the time represented by Nickles's Mount Auburn and Corryville beds there would be, on slow submergence with the beginning of the Arnheim, shallow water in which strong currents and waves might produce the phenomena of cross bedding, etc.

In this region the Oregonia division of Foerste is probably to be recognized in the part containing the characteristic fauna mentioned above, viz., *Rhynchotrema dentata*, etc. Foerste's Sunset division would doubtless include the lower cross-bedded limestone as described beyond and the part of the Arnheim below it.

In this county the Arnheim is composed of alternating layers of shale or clay and limestone as shown in Plate 3.

The character and variation of the formation is exhibited in the sections, Plate 5.

For the purpose of description, the Arnheim as delineated by the sections of Plate 5, may be conveniently divided into three parts or zones, named from prominent or characteristic fossils from below upward, the *Platystrophia ponderosa* zone, the *Rhynchotrema dentata* zone, and the *Constellaria* zone. The lowest, or *Platystrophia* zone, has at the top a coarse grained and in places, as on Brush Run, cross-bedded limestone, No. 2

Plate 3.
View showing the general character of the Arnheim formation. Cane Run 2 miles northeast of Oak Ridge School. Looking east.

Plate 4.
Lower crossbedded limestone in the Arnheim formation at roadside on Brush Run 1 mile east of Seatonsville. Looking south.

of Sections Nos. 2, 3, and 4. In Section No. 2 this limestone is strongly cross bedded as shown in Plate 4.

The limestone No. 2 of Sections 3 and 4, correlated with that of Section No. 2, is not cross bedded, but is very coarse grained and otherwise like that of Section No. 2, and there seems no doubt as to the correlation between Sections Nos. 2 and 3, but owing to the greater thickness of the supposed same bed in Section No. 4 and its greater distance below the *Rhynchotrema dentata* zone, there may be an error in its correlation with the limestone of the other two sections. Below the limestone just described, the Arnheim is made up of bluish, lumpy clay rock and shale, probably calcareous, in which are imbedded limestone layers which are generally thin and irregular, knotty, lumpy, cobbly, etc. These lower beds are well displayed in the bluff of Floyds Fork 1¼ miles northeast of Seatonsville, and illustrated in Plate 6.

The Platystrophia ponderosa zone is succeeded above by the Rhynchotrema dentata zone, so named for the occurrence, rarity, and limited range of that fossil. The rocks of this zone are mainly shale with a few thin limestone layers. These lithic characters seem to persist in the Jefferson County region and to be present as well in the type section near Arnheim, Ohio. In the Cane Run section some limestone layers, apparently in this zone, are strongly ripple marked as shown in Plate 7.

The top zone of the Arnheim is called the Constellaria zone on account of the common occurrence of *Constellaria polystonella,* which is a rather attractive and characteristic species of bryozoan. The rocks are shales and limestones as in the other divisions but there seems to be a rather larger proportion of limestone than in the lower two zones. In the Brush Run section east of Seatonsville and the Bluff section northeast of Seatonsville, Nos. 2 and 3, the base of this zone is a coarse grained limestone strongly cross bedded at the first locality. This bed seems to correspond with the heavy bed, No. 5, of the Long Run section, No. 5, and with the strongly wave-marked limestone, No. 15, of the Arnheim Section of Foerste, No. 1. The shale of this part of the Arnheim is of the characteristic dark blue Richmond and Maysville type and the limestones are unevenly layered and break up on weathering into rough surfaced irregu-

lar pieces. They are usually crowded with fossil fragments, especially with fragments of bryozoa. The character of this natural rubble is exhibited in the photograph, Plate 7.

The limestone is generally finely crystalline and dark blue in the ordinary fresh condition.

FOSSILS.—In the Platystrophia zone immediately beneath the limestone bed No. 2 of Sections 2, 3, and 4, *Platystrophia ponderosa* is remarkably abundant and many individuals are of greater size than elsewhere in the Arnheim section. They are especially plentiful on Brush Run below Clark where their source is apparently at this horizon. While a few feet of beds at this horizon are especially prolific, the form occurs throughout the lower part of the Arnheim and they are common practically down to the water 25 feet below the limestone bed No. 2 just mentioned in the bluff northeast of Seatonsville. The abundance and large size of *Platystrophia ponderosa* in these beds justifies the designation Platystrophia ponderosa zone, although the form is not confined to it. Associated with the Platystrophia in this part of the section is an occasional specimen of *Dalmanella meeki* which was not certainly collected above the limestone and seems confined to this part of the Arnheim section in this region. Constellaria and many other bryozoa, mostly undescribed forms, as well as other fossils occur, a partial list of which follows. With *Rhynchotrema dentata* the characteristic fossil of the R. dentata zone, are associated *Platystrophia ponderosa,* not abundant, and *Leptaena richmondensis.* As before mentioned this is regarded as a characteristic assemblage for the Arnheim. *Leptaena richmondensis* is not confined to this zone but ranges upward into the lower layers of the Constellaria zone and the same is true of *P. ponderosa* although both are rare in the Constellaria zone in this region. Several species of bryozoa, a few other species of brachiopods, some pelecypods and trilobites also occur in this zone and are listed below.

The upper rubbly limestone layers of the Constellaria zone are abundantly fossiliferous, the most abundant and areally prevalent forms being *Platystrophia cypha, Constellaria polystomella* from which the zone is named, and *Hallopora subnodosa* which is a widely dis-

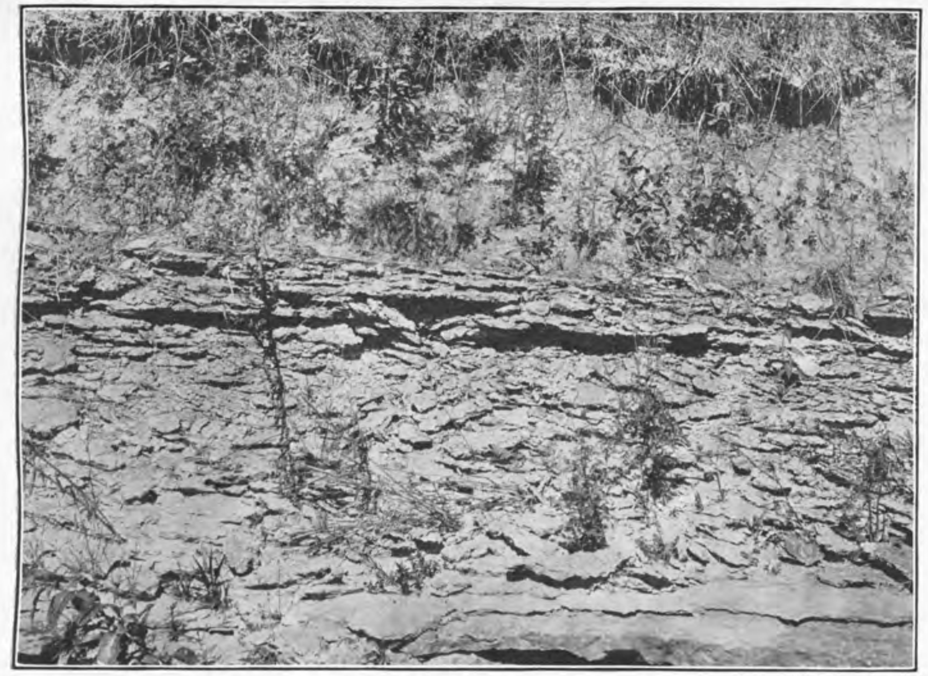


Plate 6.
Limestone rubble from the Constellaria (upper) zone of the Arnheim formation. Long Run 1 mile north of Boston. Platystrophia cypha, Hallopora subnodosa, and Constellaria pollystornella abundant here. Looking west.

Plate 7.
Ripple marked limestone in Cane Run 2 miles northeast of Oak Ridge School. Looking east.

tributed and abundant bryozoan. An occasional specimen of *Platystrophia ponderosa* is found in association with the above mentioned forms in the upper part of the zone. In the lower part of the zone *Platystrophia ponderosa* is quite common in places in the Long Run section where it is associated with *Anomalodonta gigantea*, another large pelecypod that may be *Allonychia jonesi*, and a large species of *Orthoceras* which is in places abundant. A single specimen of *Dinorthis carleyi* was found in this zone at Long Run Station, and this was the only specimen found in the county. Foerste reports it, however, from below the R. dentata zone 1 mile west of Fisherville. This form is one of the most characteristic of the Arnheim.

Below are lists of fossils from the 3 zones of the Arnheim in Jefferson County so far as they could be identified. There are a good many undescribed bryozoa that can not be listed.

Lists of Fossils From the Arnheim Formation.
(See Plate 8 for Illustrations.)

1.

Platystrophia ponderosa zone forming the lower part of the Arnheim.

Bryozoa.
Ceramoporella ohioensis. (Nicholson.)
Constellaria polystomella (Nicholson.) rare.
Corynotrypa delicatula. (James.)
Cyhotrypa sp.?
Hallopora subnodosa. (Ulrich.)
Numerous undescribed globular, encrusting, and ramose bryozoa.

Brachiopods.
Dalmanella meeki. (Miller.)
Hebertella occidentalis sinuata. (Hall.)
Platystrophia cypha conradi. (Foerste.)
Platystrophia ponderosa. (Foerste.)
Rafinesquina alternata var. (Conrad.)

Pelecypods.
Pterina demissa. (Conrad.)

Gastropods.
Cyclonema bilix fluctuatum. (James.)

2.

Rhynchotrema dentata zone.

Bryozoa.
Hallopora subnodosa. (Ulrich.)

Brachiopods.
Hebertella occidentalis sinuata. (Hall.)
Leptaena richmondensis. (Foerste.)
Platystrophia ponderosa (Foerste) rare.
Platystrophia cypha conradi. (Foerste.)
Rafinesquina alternata var. (Conrad.)
Rhynchotrema dentata arnheimensis. (Foerste.)

Gastropods.
Cyclonema bilix fluctuatum. (James.)
Lophospira bowdeni. (Safford.)

Trilobites.
Calymene meeki. (Foerste.)
Isotelus gigas. (Dekay.)

3.

Constellaria zone, upper part of the Arnheim. (See Plate 5.)

Bryozoa.
Constellaria polystomella (Nicholson), common.
Hallopora subnodosa (Ulrich), abundant.
Several undescribed globular, encrusting, and ramose forms.

Brachiopods.
Dinorthis carleyi. (Hall.)
Hebertella occidentalis sinuata. (Hall.)
Platystrophia cypha conradi (Foerste), abundant.
Platystrophia ponderosa (Foerste), rare.
Rafinesquina alternata var. (Conrad.)

Gastropods.
Cyclonema bilix fluctuatum. (James.)

Pelecypods.
Anomolodonta sp.
Anomolodonta gigantea. (Miller.)
Pterinea demissa. (Conrad.)

Cephalopods.
Orthoceras sp., large, 18 inches long (abundant in one layer.)

A few of the characteristic Arnheim fossil forms are illustrated on Plate 8. Most of these should be easily identified by any one interested, and the presence of any one in the rocks of this county at any point is sufficient to show that they belong to the Arnheim formation.

Fossils of the Arnheim Formation and Waynesville Limestone.
Plate 8.

1-2 Dalmanella meeki. (Miller.) 1, brachial; 2, pedicle valve. Arnheim formation only, in Jefferson County.

3-4 Constellaria polystomella. (Nicholson.) 1. View of a piece of a frond, natural size. 2. A small part of the surface of 1 enlarged 15 diameters. Common and characteristic bryozoan of the Arnheim formation. Rare except in the Constellaria zone forming the top member of the Arnheim in which it is rather abundant in places and to which it gives the name.

5-6 Hallopora (Callopora) subnodosa. (Ulrich.) 5. View of branch, natural size. 7. Portion of surface enlarged 15 diameters showing cell mouths. Common throughout the Arnheim, less common in the Waynesville.

7-8 Cyphotrypa clarksvillensis. Ulrich. 7. View of a complete specimen natural size showing the flattened base. 8. Portion of the surface enlarged 15 diameters. Common throughout the Waynesville and abundant in the Cyphotrypa shale bed near the bottom of the Waynesville. The species is easily recognizable from its globular form to which there is nothing else similar in the rocks of the county. Being common and limited to the Waynesville, it is a sure index for the identification of that formation.

9 Cyclonema bilix fluctuatum. James. Common in the Arnheim to which it is apparently confined.

10-12 Platystrophia cypha. Foerste. After Foerste. 10, front; 11 pedicle; and 12, brachial view. Abundant in the Arnheim formation.

13-14 Zygospira kentuckyensis. James. After Nettelroth. 13, brachial; 14, pedicle valve. Apparently confined to a thin zone in the upper 15 feet of the Waynesville where it is fairly common.

15 Leptaena richmondensis. Foerste. View of a pedicle valve. Arnheim formation to which it is apparently confined in Jefferson County.

16-17 Dinorthis carleyi. Hall. 16, pedicle; 17, brachial valve. Arnheim only. Very rare in Jefferson County. The only specimen found occurred in the Constellaria zone.

18-19 Platystrophia ponderosa. Foerste. 18, pedicle; 19, brachial valve. Medium sized specimen. Specimens ½ larger are common. Arnheim only. Very abundant in the lower Arnheim which is therefore called the Platystrophia ponderosa zone.

20 Anomalodonta gigantea. Miller. After Ulrich. View of a left valve. Arnheim only. Common.

21-23 Rhynchotrema dentata arnheimensis. Foerste. 21, pedicle; 22, brachial; and 23, profile view. Confined to the Rhynchotrema dentata zone near the middle of the Arnheim where it is fairly common.

AGE AND CORRELATION.—The Arnheim is the basal formation of the Richmond group which is now correlated in part or in whole with the Queenston shale ("red Medina"), of New York. This correlation is based on the presence of Richmond fossils in beds intercalated in the Queenston shale to the north of Lake Huron whence the red shale can be traced continuously into its type locality a few miles north of Niagara Falls. The Arnheim has been recognized in the vicinity of Clifton, Tennessee, on the Tennessee River; in Sequatchie Valley, Tennessee, and east of Walden Ridge in the Appalachian Valley,

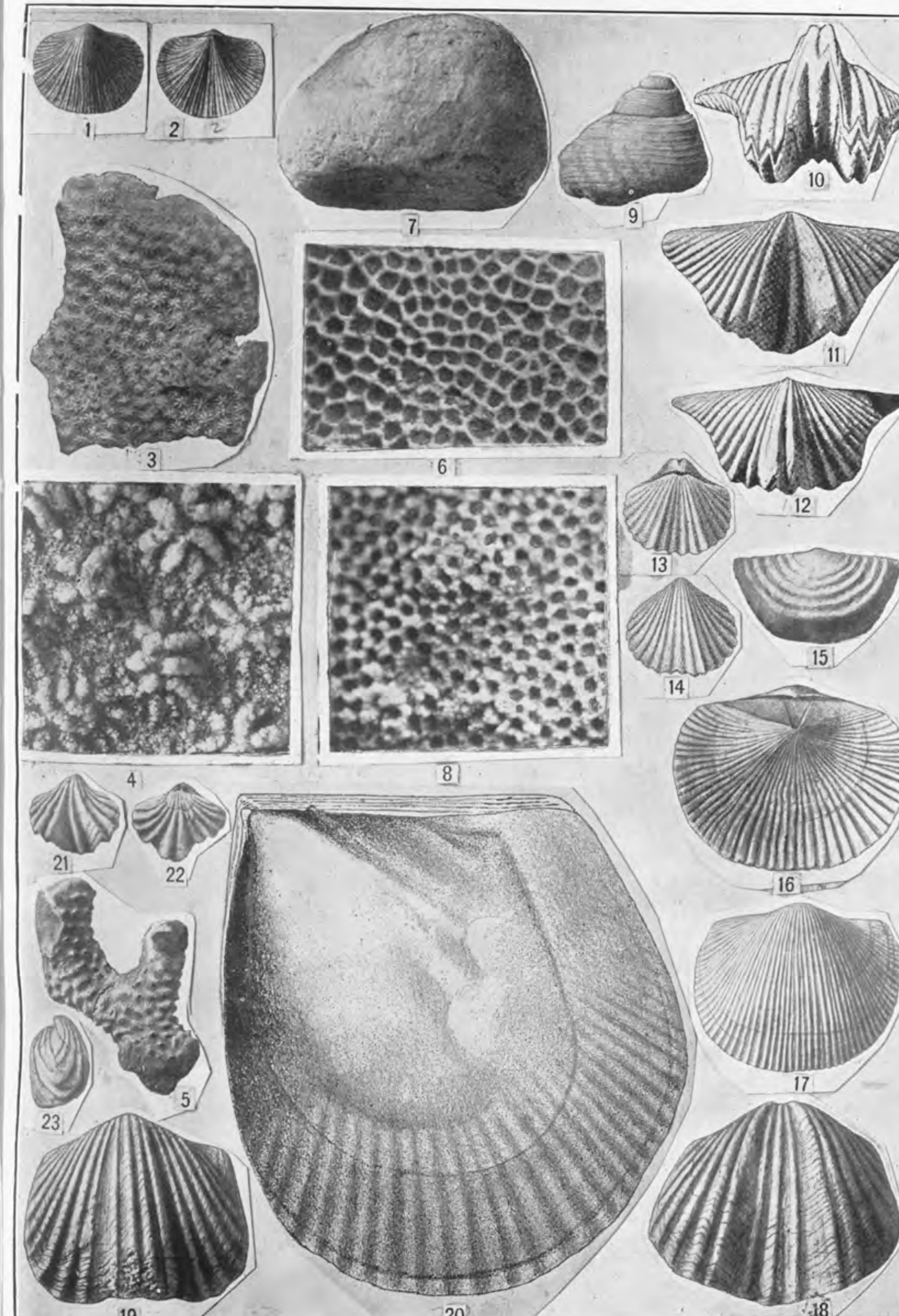


Plate 8.
Fossils of the Arnheim formation and Waynesville limestone.

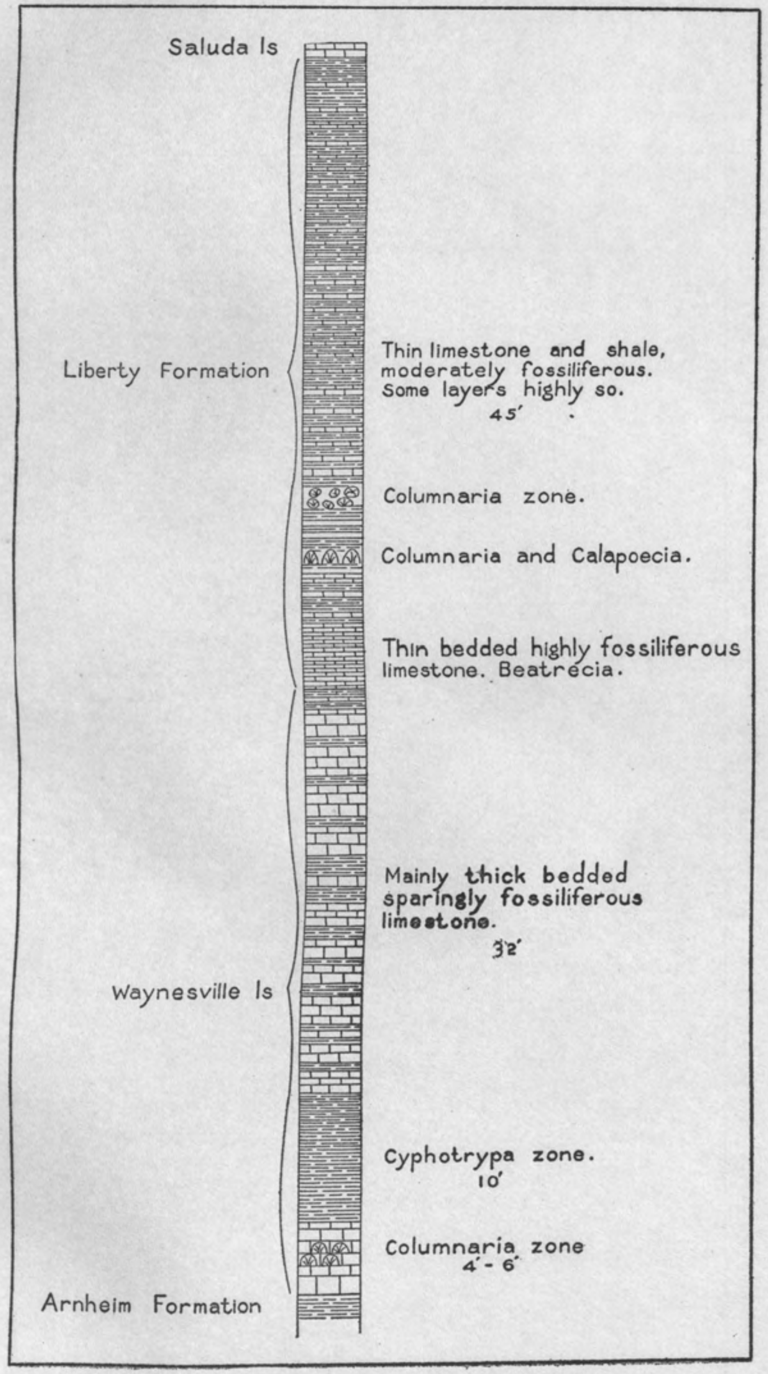


Fig. 2. General section of the Liberty and Waynesville formations.

where it is represented by part of the lower half or two-thirds of the "Rockwood" formation. The correlation of the Arnheim of Jefferson County with the Arnheim at the type locality as established by Foerste has already been discussed.

WAYNESVILLE LIMESTONE.

NAME AND DEFINITION.—The name Waynesville, introduced by Nickles,* is from Waynesville, Ohio, where the formation is mostly shale. In this part of Kentucky the name includes mostly heavy limestone about 40 feet thick lying between the Arnheim formation below, and the Liberty formation above, both of which are very different from the Waynesville in lithic character.

DISTRIBUTION.—The Waynesville limestone has extensive belts of outcrop along the middle and lower parts of all the valley walls in the Floyds Fork drainage area in the southeastern one-fourth of the county.

THICKNESS.—The Waynesville appears to vary in thickness between 40 and 50 feet, with 45 feet as a fair average.

CHARACTER.—The Waynesville is mostly a thick-bedded limestone, but has in its lower part a persistent and distinctive bed of shale. A detailed section which is very constant throughout the county is shown in Fig. 2. At the bottom of the Waynesville is a persistent bed of medium thick-bedded argillaceous limestone of compact earthy texture and drabish color. The most striking feature of this bed is the presence in some of the layers of the rounded heads up to 1 foot in diameter, of a coral, *Columnaria alveolata,* which is either common or abundant at nearly every point at which the bed was observed. The bed is an old coral reef which spread widely over the sea bottom of the time, but was not of long duration, as is indicated by its slight thickness. From the presence of this coral the bed is called the Columnaria zone (see Section, Fig. 2). This coral and the peculiar texture and color of the bed serve for its certain identification. The bed is persistent throughout the county, having been observed at all points where the rocks at its horizon are

*Nickles, J. M. The Richmond Group in Ohio and Indiana. Am. Geologist, vol. 32, pp. 205-206, 1903.

exposed. It immediately overlies the Arnheim formation and clearly belongs to the Waynesville on account of its lithic character.

Above the Columnaria zone is another peculiar stratum which is a shale about 10 feet thick, predominantly gray but of a greenish cast, due to the presence of green mottlings which are probably caused by the presence of ferrous silicate. The bed weathers to a yellowish green clay. It is especially characterized by a globular bryozoan, *Cyphotrypa clarksvillensis,* specimens of which are everywhere present and in most places fairly plentiful. (See Plate 9.) The bed is persistent in all its features throughout the county and at many places one can find a weathered bank of yellowish green clay or decayed shale on which numbers of the globular bryozoan can be collected in a few minutes' search. (See Plate 8, Figs. 7 and 8.) The stratum is designated the Cyphotrypa zone, a photograph of which is shown in Plate 9.

The upper 32 feet of Waynesville limestone is predominantly composed of limestone, argillaceous, greenish grey, non-granular, compact, and thick bedded. Thin shale partings are present throughout and in the upper 10 feet or so shale forms a considerable part of the section. The general character of the bedding in the fresh condition is shown in Fig. 2, and on Plate 10. On exposure to the weather, these limestone layers break up and weather out into large, rounded bowlders, which are unique in appearance and can be unfailingly recognized. In places they literally pave the surface. A notable locality for such a display is just east of the county on the hill between the two headwater branches of Cane Run, as shown on Plate 11. Owing to the earthy impurities of this limestone it weathers out with a light grey or whitish and roughened surface which makes conspicuous any areas on which the bowlders are present in any considerable numbers.

FOSSILS.—Fossils are not abundant in number or species in the Waynesville of this region. Besides the *Columnaria* a few other fossils are present, in the Columnaria zone, the most conspicuous of which is a large gastropod *Lophospira bowdeni.*

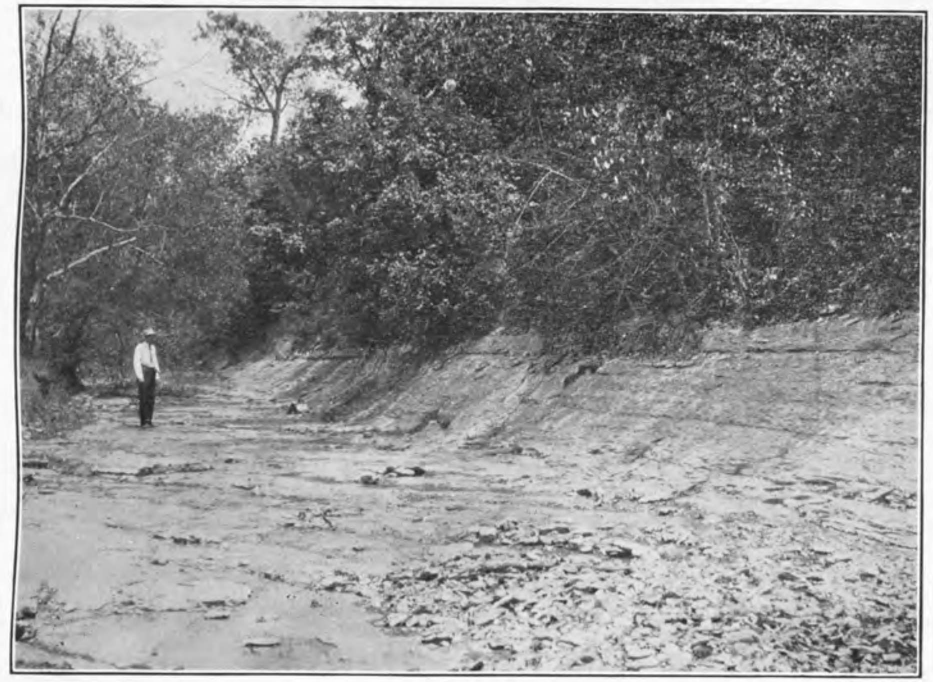


Plate 9.
Cyphotrypa (greenish shale) zone in creek bank ½ mile due north of Eastwood. Looking northeast.

Plate 10.
Waynesville limestone, middle part, about 16 feet thick, exposed in a quarry on Brush Run 2¼ miles east of Seatonsville. Looking southeast.

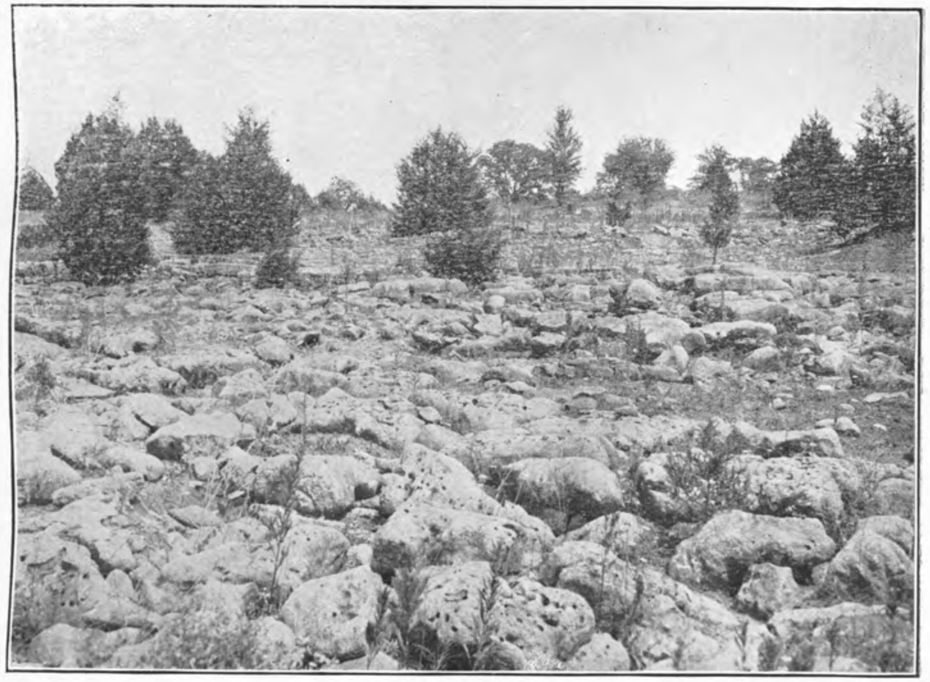


Plate 11.

Bowlders from the middle part of the Waynesville limestone. Hill just east of the county between the two headwater branches of Cane Run. Represents a common condition in the county. Looking northeast.

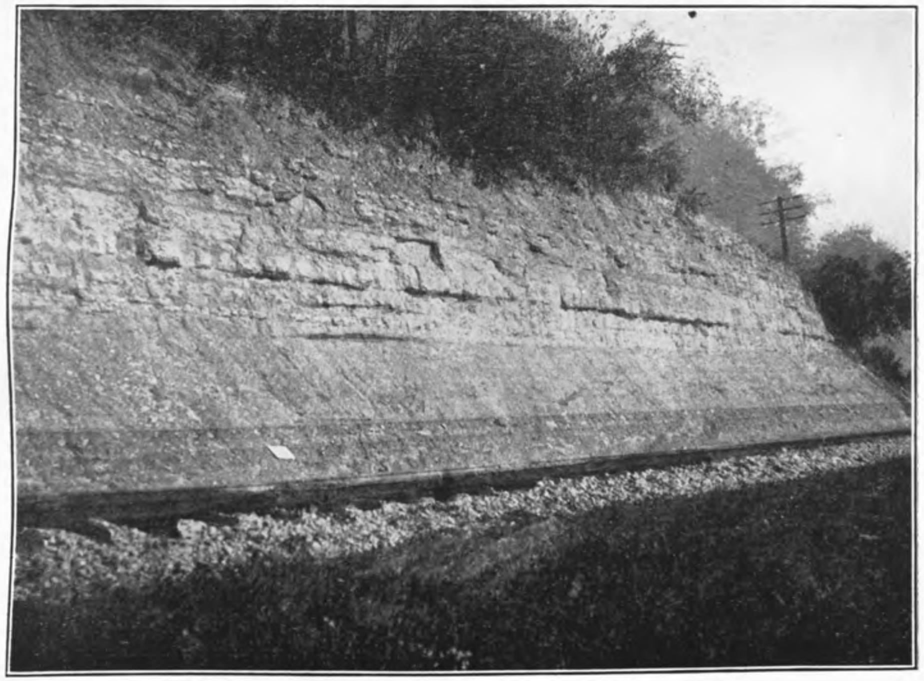


Plate 12.

Waynesville limestone in railroad cut 1 mile north of Pendleton, Henry County, Ky. Book lies on Columnaria bed at bottom of formation. Looking northeast.

The *Cyphotrypa (C. clarksvillensis?)* is confined to the Waynesville and its presence is diagnostic. As it is easily recognizable and ranges nearly through the formation from top to bottom and is abundant in the Cyphotrypa zone as well as common in the part of the Waynesville above that bed, it is a very serviceable fossil form for identifying that formation.

Fossils occur throughout the upper part of the Waynesville sparingly. The *Cyphotrypa* already mentioned occurs though generally it is not as plentiful as in the Cyphotrypa zone. *Zygospira kentuckyensis* (Plate 8, Figs. 13 and 14), is a characteristic fossil of this zone. The forms identified are listed below:

List of Fossils From the Waynesville Limestone.

1.

Columnaria zone at base of Waynesville.

Corals.
- Columnaria alveolata. (Goldfuss.)
- Tetradium approximatum. Ulrich.

Bryozoa.
- Hallopora subnodosa. (Ulrich.)

Brachiopods.
- Hebertella occidentalis sinuata. (Hall.)
- Platystrophia cypha—var. Foerste.

Pelecypods.
- Ctenodonta sp.?
- Pterinea demissa. (Conrad.)

Gastropods.
- Lophospira bowdeni. (Safford.)

2

Cyphotrypa zone.

Bryozoa.
- Cyphotrypa clarksvillensis. Ulrich. Large globular form ½ to 1½ in. diameter (abundant).

Brachiopods.
- Hebertella occidentalis sinuata. (Hall.)
- Platystrophia cypha—var. Foerste.

Cephalopods.
- Orthoceras sp.? rare.

3.

Upper part of Waynesville.

Bryozoa.
- Cyphotrypa clarksvillensis Ulrich, common.
- Ramose bryozoa undescribed forms.

Brachiopods.
- Hebertella occidentalis sinuata. (Hall.)
- Platystrophia cypha—var.
- Zygospira kentuckyensis. James.

Gastropods.
- Lophospira bowdeni. (Safford.)

Pelecypods.
- Byssonychia sp.?

Ostracods.
- Reticulated and other forms.

Some of the most important of these fossils are illustrated in Plate 15.

AGE AND CORRELATION.—In its position with reference to overlying and underlying formations as well as in its fossils the limestone here described corresponds to the Waynesville formation of the Richmond group of Indiana and Ohio. In its type locality, however, the Waynesville is predominantly shale, while in this part of Kentucky the formation is predominantly a thick bedded limestone. The typical Waynesville (shale) facies prevails northward in Indiana and Ohio and the limestone facies prevails southward in Kentucky including the Jefferson County region. In going northward from Jefferson County, the peculiar limestone facies persists as far as Pendleton in Henry County, but is absent or thin and not recognizable at Madison, Indiana. At Pendleton the formation has changed to a thick bedded, calcareous mud rock, and its thickness is less than in this county. This aspect of the Waynesville is exhibited in Plate 12. The presence of *Cyphotrypa clarksvillensis* would point to the conclusion that the Waynesville of this county corresponds to the upper division (Clarksville of Foerste) of the Waynesville of Ohio.

LIBERTY FORMATION.

NAME AND DEFINITION.—The Liberty was named by Nickles* from the town of Liberty, in Union County, Indiana. The Liberty is distinctly bounded below by the characteristic greenish-gray, argillaceous, sparingly fossiliferous Waynesville limestone. The upper limit of the Liberty is less definite, but can vary only within the narrow limits of 5 to 10 feet below the bottom of the characteristic heavy-bedded, color-banded, siliceous limestone constituting the main part of the Saluda limestone in Jefferson County. The typical shale and thin bedded limestone of the Liberty grades at top into a sort of coarse mud rock 3 to 5 feet thick, which underlies a bed carrying *Columnaria alveolata*, which is assigned to the Saluda. This Columnaria zone is generally absent in Jefferson County, however, being known in only one locality, but a bed with *Tetradium* a foot or two above the Columnaria zone and directly beneath the heavy siliceous stratum of the Saluda limestone is usually present and is a good marker for the boundary between the Liberty and the Saluda, since there is probably not to exceed 5 feet of mud rock of Saluda type below the Tetradium zone and between it and the Liberty formation in Jefferson County. Both the Columnaria and Tetradium zones are widely distributed to the north of this region and serve as reliable guides in correlation. At Madison, Indiana, there is 12 feet of such rock below the Columnaria zone and about 20 feet of it below the Tetradium zone. These relations are illustrated by the sections of Plate 16.

DISTRIBUTION.—The Liberty formation outcrops only in the eastern part of the county. On the east of Floyds Fork it outcrops on or not far below the tops of the ridges or spurs and on the west side its outcrop extends well up toward the heads of the streams. On Chenoweth Creek, for example, its outcrop extends up the creek as far as Jeffersontown. Owing to the west dip of the strata it does not come to the surface in the western part of the county, but it is supposed to be probably about 200 feet beneath the surface at the "Falls of the Ohio."

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*Nickles, J. M. Am. Geol., vol. 32, p. 208, 1913.

THICKNESS.—At Eastwood, where both the top and bottom of the Liberty may be seen, the thickness of the formation is 50 feet. This thickness holds very nearly for the whole area of its exposure in the county. At only one point was a less thickness determined, and that is on the highway on the bluff about a mile west of Seatonsville, where, according to a reliable measurement, the thickness is 36 feet.

CHARACTER.—The Liberty formation is very uniform in its composition, being made up from top to bottom of bluish shale or mud rock, probably calcareous, in which are numerous thin layers of blue, fine-grained limestone, both shale and limestone being fossiliferous and especially so in the lower 5 to 10 feet. The prevailing character of the formation is clearly exhibited in the railroad cut at Eastwood, a photograph of which is given in Plate 13. The lower 5 feet of the Liberty is almost all thin bedded limestone of the same general type as the separated layers in the rest of the formation. This limestone is highly fossiliferous and yields the abundant fossiliferous limestone debris that is generally scattered on the surface at this horizon. It can be seen in place on Chenoweth Creek, about 1 mile east of Jeffersontown, and a short distance down the creek below the highway its contact with the underlying Waynesville limestone is clearly exposed and the strong contrast between the two formations can be seen.

About 5 feet above this limestone and 10 feet above the bottom of the formation is a thick layer of limestone containing numbers of big heads of *Columnaria,* some as much as 4 or 5 feet across. About 5 feet higher at this locality is another reef of *Columnaria* in which the heads are smaller and more abundant. The lower Columnaria zone or reef is persistent throughout the county, its loose heads, generally of smaller dimensions than those stated above, being found almost everywhere at the outcrop of the base of the Liberty. With it are associated in the same layer another coral, *Calapoecia cribriformis,* also forming heads which, however, are much smaller than the *Columnaria* heads. The upper coral reef was observed only in the vicinity of Jeffersontown and may or may not be present elsewhere. The upper 30 to 35 feet of the Liberty is essentially a uniform succession of blue

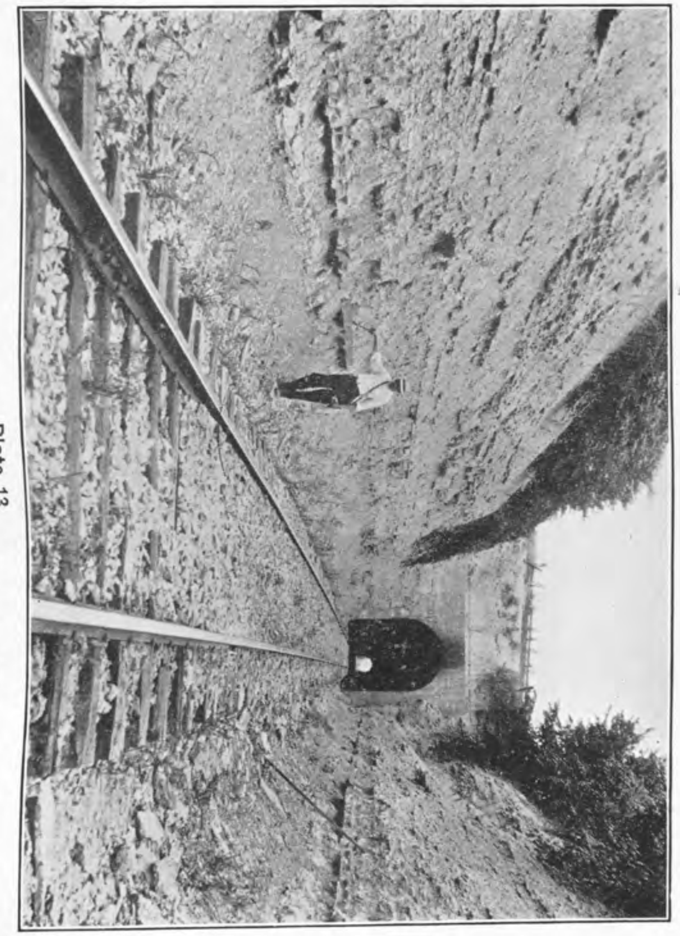


Plate 13.
Liberty formation in railroad cut at Eastwood. Lower 5 feet or so of formation not exposed. Top just above top of cut above portal of tunnel. Looking east.

clay, shaly rock and thin limestone layers as shown in the railroad cut at Eastwood. Various of these limestone and shale layers are highly fossiliferous, the most striking forms being the brachiopods such as *Rhynchotrema capax, Strophomena planumbona, Rafinesquina sp.?, Hebertella sinuata, Platystrophia sp.?, and Dinorthis subquadrata*. The first five are common to abundant, while the last is rare in Jefferson County. *Hebertella insculpta,* whose lowest occurrence marks the bottom of the Liberty to the north of this region, has not been found in this part of Kentucky. Except *D. subquadrata,* which seems to occur only near the middle of the formation, the brachiopods range through its full thickness. Another characteristic and striking form is the cup coral, *Streptelasma rusticum,* which also ranges from bottom to top of the formation and is abundant in some layers. Bryozoa are very abundant throughout the Liberty. One of the most characteristic and most widely ranging geographically of these is *Rhombotrypa quadrata,* so named from the quadrate shape of its cells. A list of the fossils of the Liberty formation is given below. Illustrations of species which are confined to the Liberty in this region are given on Plate 15.

List of Fossils From the Liberty Formation.

Corals.
- Beatricea nodulosa. Billings.
- Beatricea undulata. Billings.
- Calapoecia cribriformis. Nicholson.
- Columnaria calicina. Nicholson.
- Columnaria vacua. Foerste.
- Protarea richmondensis. Foerste.
- Streptelasma divaricans. (Nicholson.)
- Streptelasma rusticum, Billings, very abundant.

Bryozoa.
- Arthropora shaefferi (Meek), var. robusta.
- Graptodictya perelegans. Ulrich.
- Homotrypella (Prasopora) hospitalis. (Nicholson.)
- Rhombotrypa quadrata. (Rominger.)
- Several undescribed ramose bryozoa.

Brachiopods.
- Dinorthis subquadrata (Hall), rare.
- Hebertella occidentalis sinuata. (Hall.)
- Leptaena richmondensis. Foerste.
- Platystrophia annieana. Foerste.
- Plectambonites rugosus clarksvillensis. Foerste.
- Rafinesquina alternata var. (Conrad.)
- Rhynchotrema capax, Conrad, abundant.
- Strophomena planumbonum, Hall, abundant.
- Zygospira kentuckyensis. James.
- Zygospira cf. recurvirostris. Hall.

Pelecypods.
- Byssonychia sp.?
- Opisthoptera fissicosta. Meek.

Gastropods.
- Cyclonema bilix. Conrad.

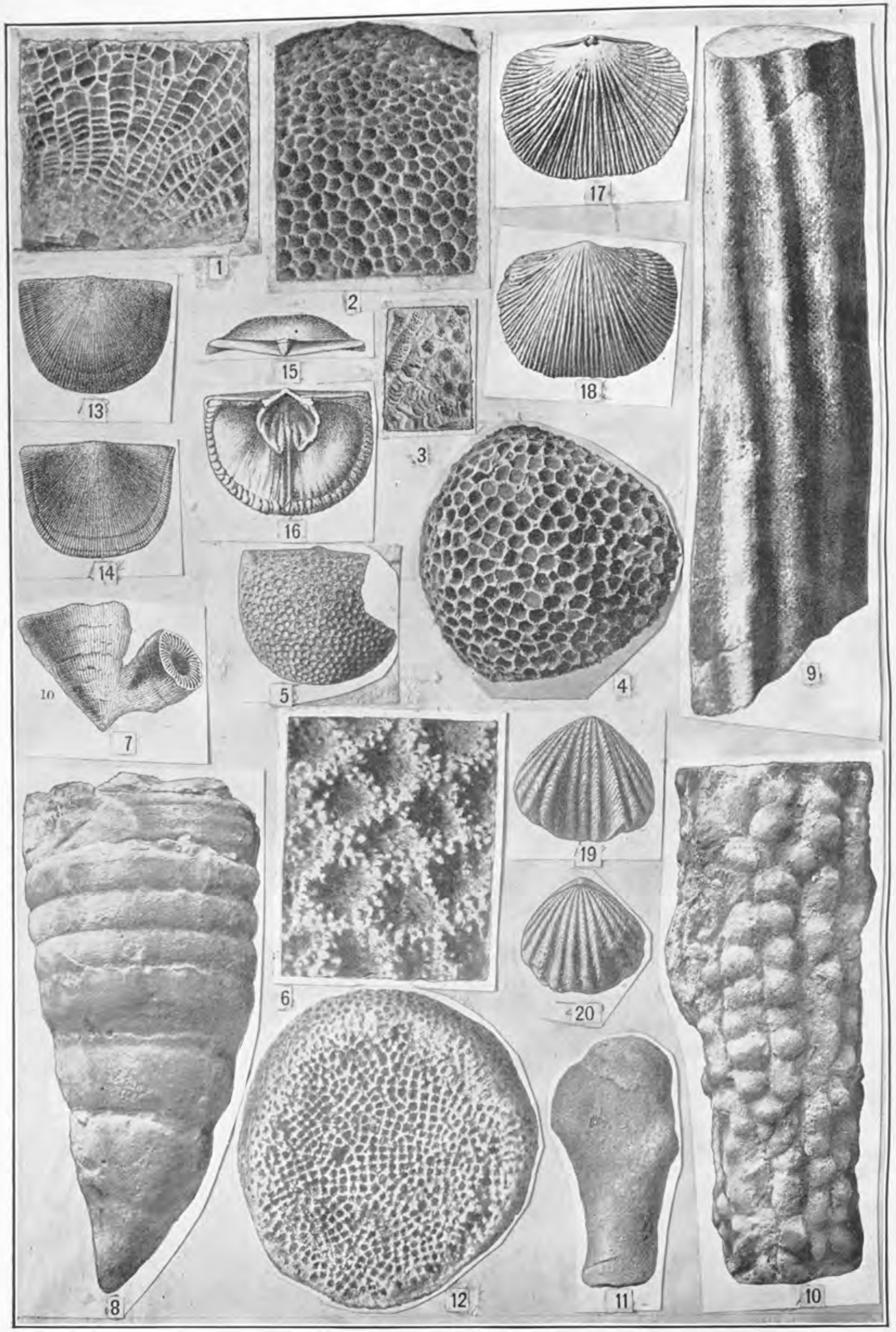


Plate 15.
Fossils of the Liberty formation and Waynesville and Saluda limestones.

Fossils of the Liberty Formation, Waynesville and Saluda Limestones. Plate 15.

1-2 Columnaria alveolata. Goldfuss. After Davis. Coral. 1, Section showing tubes and tabulae; 2, surface of head showing cell mouths and septae extending to center. Waynesville limestone. Columnaria calcina forming the large heads in the base of the Liberty is very similar to this species and Columnaria vacua, also near base of Liberty, differs from C. alveolata in lacking the well developed septa.

3-4 Calapœcia cribriformis. Nicholson. After Davis. Common coral of the Liberty formation. 4, view of exterior of small head showing cell mouths with rudimentary septae or carinae on the cell walls; 3, portion of the base of another specimen showing the radiating cells with many relatively large pores penetrating the cell walls between the carinae. Basal part of the Liberty limestone only in Jefferson County, associated with Columnaria calcina.

5-6 Protarea richmondensis. Foerste. A common coral of the Liberty formation. 5, specimen natural size encrusting a brachiopod shell; 6, enlarged view of the same.

7 Streptelasma divaricans. (Nicholson.) After Meek. Hitz limestone member of the Saluda. Common.

8 Streptelasma rusticum. Billings. Abundant coral of the Liberty formation to which it seems to be confined in Jefferson County.

9 Beatricea undulata. Billings. After Foerste.

10 Beatricea nodulosa. Billings. The forms illustrated by figures 9 and 10 are supposed to be related to the corals or sponges. Basal part of the Liberty formation only. Common.

11-12 Rhombotrypa quadrata. Rominger. A common and characteristic bryozoan of the Liberty formation. 11, part of a branch natural size; 12, end view of a small stem enlarged 6 times showing the characteristic quadrate cells.

13-16 Strophomena planumbonum. Hall. After Meek. 13, brachial; 14, pedicle; 15, cardinal view; 16, interior of a pedicle valve, a common condition of preservation. Liberty formation only, in Jefferson County. Very abundant.

17-18 Dinorthis (Orthis) subquadrata. (Hall.) Characteristic brachiopod of the Liberty formation. Rare in Jefferson County. 17, pedicle; 18, brachial valve.

19-20 Rhynchotrema capax. Conrad. Charasteristic brachiopod of the Liberty. Abundant. 19, pedicle; 20, brachial valve.

AGE AND CORRELATION.—According to Ulrich the Liberty formation in this county is the practical equivalent of the Liberty as known in Ohio and Indiana.

The Liberty and Waynesville formations in Ohio and Indiana constitute the middle part of the Richmond group and may be represented by the middle part of the Queenston ("red Medina") shale of New York. Fossils of Liberty age such as *Rhynchotrema capax* and *Rhombotrypa quadrata* have been found in the north end of Big Wills Valley a few miles southwest of Chattanooga, Tennessee, and possibly indicate deposits of Liberty age in that region. It is not improbable that this middle formation of the Richmond is represented in Sequatchie Valley and east of Walden Ridge by non-fossiliferous, argillaceous, red mottled limestones with layers of red shale overlying a heavy limestone bed with *Platystrophia ponderosa*, which is referred to the Arnheim. These impure, mottled limestones with a few layers of red shale, compose the lower part of the "Rockwood" formation of Tennessee. According to Ulrich also the Waynesville and Liberty are in part represented by the Maquoketa shale and Thebes formation of Eastern Missouri and of southwestern Illinois.

SALUDA LIMESTONE.

NAME AND DEFINITION.—The name Saluda was introduced by Foerste* from Saluda Creek, 6 miles south of Hanover, Indiana, and 10 miles southwest of Madison, Indiana. Saluda replaced the earlier name, "Madison beds," from Madison, Indiana, owing to the preoccupation of the latter name. As described by Foerste, the Saluda at Madison extends downward to the bottom of the Columnaria reef shown in the Madison section, Plate 16, Section 4.† As defined at the type locality, however, where the Columnaria reef is absent, the Saluda extends down to the highly fossiliferous beds of the Liberty formation. Foerste‡ defines the bottom of the Saluda as follows: "While the coral bed is practically absent along Saluda Creek, the section nevertheless is sufficiently distinct to enable anyone to draw the line between the nearly unfossiliferous base of the Saluda bed and the richly fossiliferous beds of the Richmond immediately underneath." The section at Madison shows that there is 12 feet of shale, limestone, and mud rock below the Columnaria zone extending down to the top of the highly fossiliferous beds of the Liberty; also Foerste's sections on Pl. XXI. of the American Geologist cited above, show, in the Madison section, about 12 feet of unclassified beds between the Columnaria zone and the top of the Liberty. These beds are identical in character with the remainder of the section above the Columnaria zone, extending up to the heavy siliceous limestone, and they clearly belong with the Saluda and are here so included, as the definition of the Saluda clearly permits. The top of the Saluda, either at the type locality or elsewhere, has not been specifically defined by Foerste, at least in any publications examined by the writer. In plate XXI., of Vol. 31 of the American Geologist already cited, however, he shows in the sections the Saluda extending up to the Brassfield limestone (at that time regarded as Clinton), generally accepted as forming the base of the Silurian.

*Foerste, A. F., Am. Geol., vol. 30, p. 369, Dec., 1902.

†Foerste, A. F., loc. cit. Also Am. Geol., vol. 31, No. 6, Pl. XXI., op. p. 348, where the bottom of the Saluda is drawn at the bottom of the Columnaria zone, in the section at Madison and at the top of the Liberty formation in the section at Hanover.

‡Loc. cit.

That usage may be accepted as the author's conception of the upper limit of the Saluda, although in describing in an earlier paper* the "Madison bed," the name of which is replaced by Saluda, Foerste appears to exclude from the "Madison" the Hitz limestone (Murchisonia hammelli zone), which, in the plate referred to just above, is included by him in the Saluda. The Saluda formation is thus defined as extending from the top of the Liberty formation below to the bottom of the Brassfield limestone above. It includes at the top the thin Hitz limestone member. The general character and relations of the Saluda limestone are exhibited in the sections of Plate 16.

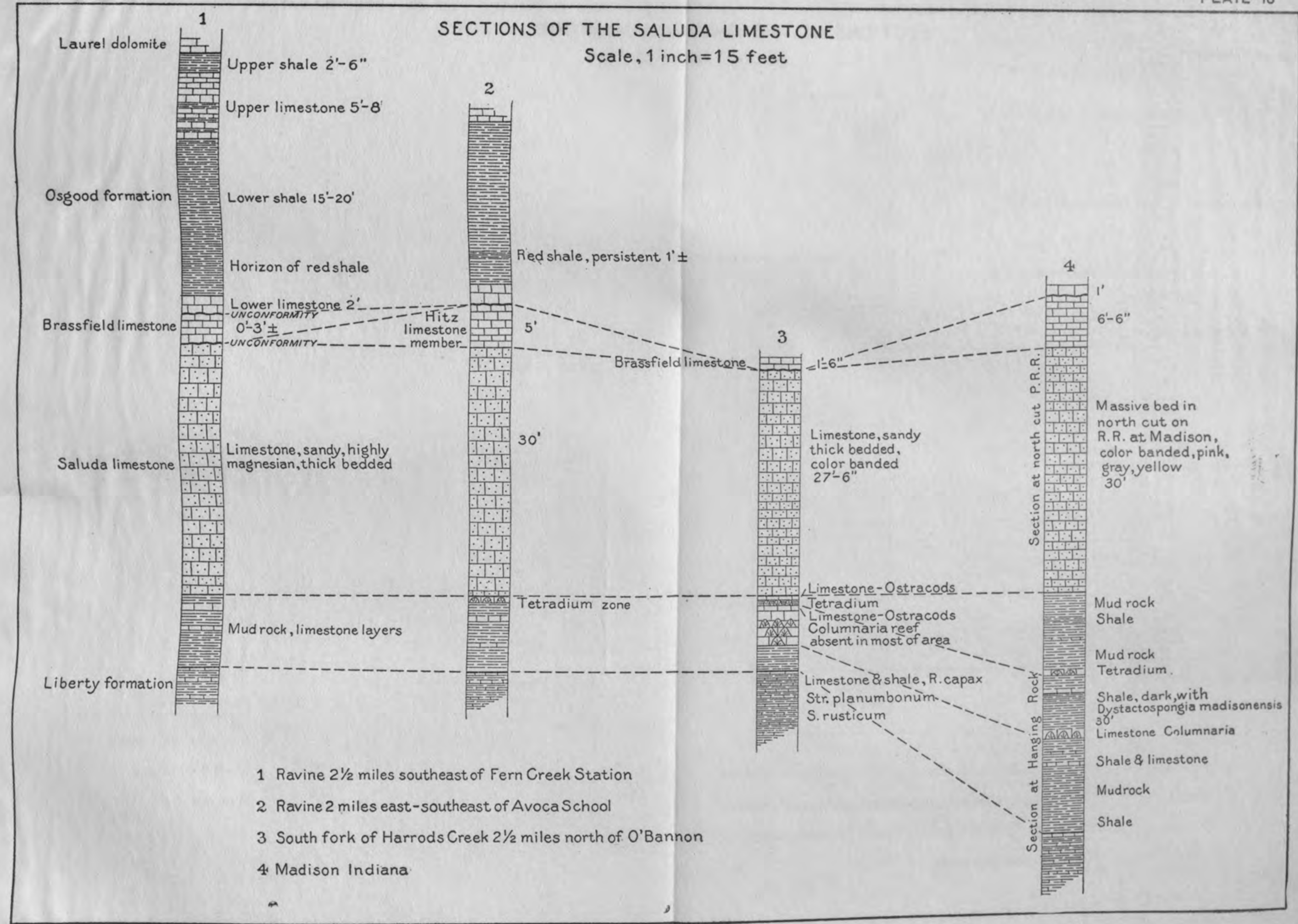
DISTRIBUTION.—The Saluda limestone outcrops only in the eastern one-third of Jefferson County, in the Floyds Fork drainage area, and is there largely confined to the tops of the spurs and ridges except along the western edge of its outcrop extending from the point where Floyds Fork crosses the northeast boundary of the county, via Jeffersontown and Tucker to the south boundary on Floyds Fork. Along this line the Saluda descends into the bottom of the valleys and extends westward beneath the overlying formations.

THICKNESS.—In Jefferson County the whole Saluda, including the Hitz member, does not vary greatly from 40 feet in thickness, of which the upper thick bedded sandy limestone comprises about 30 feet. On the Waterford road just south of the county and a mile or so east of Floyds Fork, the latter division is only about 25 feet thick.

CHARACTER.—In Jefferson County, as shown in the sections, Plate 16, the Saluda is almost wholly composed of sandy and highly magnesian limestone, but the lower 8 to 10 feet is generally coarse, lumpy, mud rock with two layers of rather fine blue limestone. The sandy limestone makes up three-fourths of the whole thickness. At the very bottom the 5 feet more or less of mud rock seems to grade downward into the Liberty in such a way as to make it uncertain where the boundary between the Liberty and Saluda should be located. The

*Foerste, A. F., Ind. Dept. Geol. & Nat. Res., 21st Ann. Rept., pp. 218-222, 1896.

PLATE 16


SECTIONS OF THE SALUDA LIMESTONE
Scale, 1 inch=15 feet
1
2
3
4
Laurel dolomite
Upper shale 2'-6"
Upper limestone 5'-8'
Osgood formation
Lower shale 15'-20'
Horizon of red shale
Lower limestone 2'
UNCONFORMITY
Brassfield limestone
0'-3' ±
UNCONFORMITY
Hitz limestone member
5'
Red shale, persistent 1' ±
Saluda limestone
Limestone, sandy, highly magnesian, thick bedded
30'
Tetradium zone
Mud rock, limestone layers
Liberty formation
Brassfield limestone
1'-6"
Limestone, sandy thick bedded, color banded 27'-6"
Limestone-Ostracods
Tetradium
Limestone-Ostracods
Columnaria reef absent in most of area
Limestone & shale, R. capax
Str. planumbonum
S. rusticum
1'
6'-6"
Section at north cut P.R.R.
Massive bed in north cut on R.R. at Madison, color banded, pink, gray, yellow 30'
Mud rock
Shale
Mud rock
Tetradium
Shale, dark, with Dystactospongia madisonensis 30'
Limestone Columnaria
Shale & limestone
Mudrock
Shale
Section at Hanging Rock
1 Ravine 2½ miles southeast of Fern Creek Station
2 Ravine 2 miles east-southeast of Avoca School
3 South fork of Harrods Creek 2½ miles north of O'Bannon
4 Madison Indiana

shale in the upper part of the Liberty formation is so nearly like the mud rock of the lower part of the Saluda that they can not be readily distinguished and it is only by the presence of the thin, fossiliferous limestones of Liberty type that the boundary is marked. Generally, however, these limestone layers begin to come in within 10 feet below the base of the heavy sandy limestone about which there is no doubt, or 8 or 9 feet below the Tetradium reef that in most sections is present close below the bottom of the heavy limestone.

The general character of the two divisions of the Saluda and the upper part of the Liberty, as exposed in the railroad cut at Madison, is shown on Plate 14. The mud rock is of greenish-grey color, or, on weathering, tinted externally with brownish, pinkish or yellowish color. It is non-fissile and lumpy and strongly suggestive of a hardened mud. In this mass at some points are two layers of even surfaced, fine textured, blue limestone 6 inches thick. Also generally there are present just beneath the sandy limestone, nodular masses of nearly white crystalline limestone, which are in reality heads of the coral *Tetradium*, the squarish radiating tubes of which can be easily seen with a magnifying glass.

A variation from the general condition in Jefferson County just described exists on the headwaters of the south fork of Harrods Creek to the west of Pewee Valley. This locality is just northeast of the county boundary and 2 to 3 miles nearly due north of O'Bannon. Here, as shown in the Jefferson County sections (Plate 16), the lower part of the Saluda is composed of thin layers of limestone and clay or shale, as described in the following section:

Section of the Saluda Limestone on the Headwaters of the South Fork of Harrods Creek, 2-3 miles north of O'Bannon.

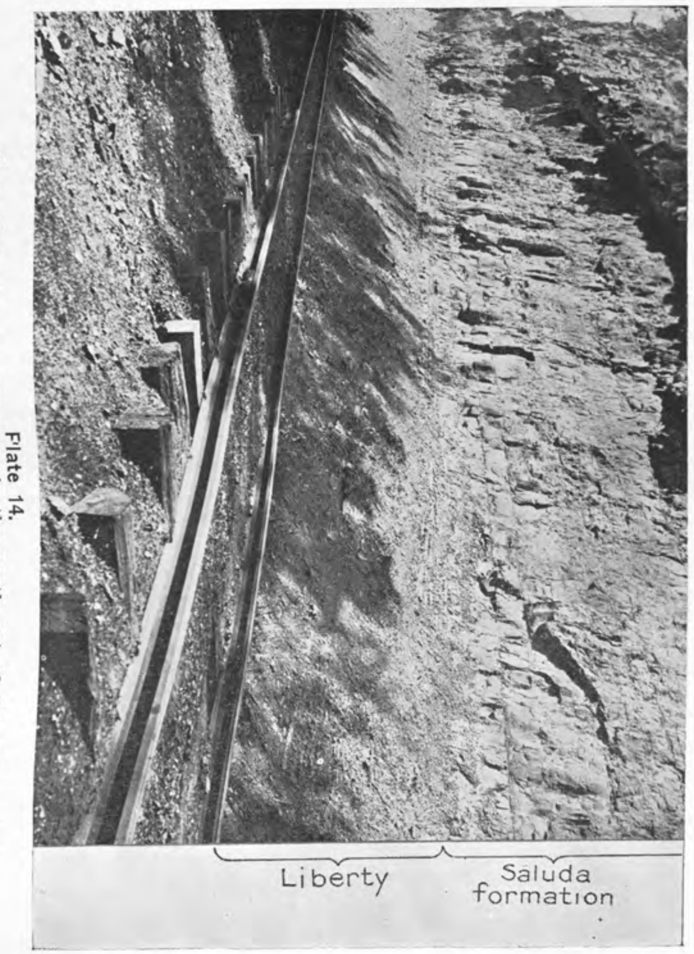
	Ft.	Ins.
Brassfield limestone:		
10. Limestone	1	6
Saluda limestone:		
9. Limestone, sandy, thick-bedded	29	
8. Limestone, light blue, fine grained (ostracods.)		3
7. Mud rock		3
6. Clay, blue, abundant large discoid heads of Tetradium. Seems to grade laterally in a short distance into bluish fine-grained limestone weathering white. Many gastropods, also Ctenodonta, ostracods and bryozoans		6
5. Limestone, blue, fine-grained, ostracods and occasional Tetradium head		8
4. Limestone, bluish, argillaceous, cobbly, weathers white. Occasional specimen of Hebertella sinuata and Zygospira	1	
3. Limestone, hard, blue, fine-grained, with thin partings of brown weathering, siliceous limestone or mud rock. Large Columnaria heads within the bed or upon its surface and growing up into No. 4. This bed grades below into No. 2	3	
2. Mud rock, greenish, 3 inch layers, crumbly	3*	
Total Saluda	37	8
Liberty formation:		
1. Limestone and shale. Limestone layers few, thin, hard, blue, shale, rather fissile but irregularly so	2*	

Another interesting section of this zone is exposed on the southern branch of the South Fork of Harrods Creek just 2 miles almost due north of O'Bannon.

*More or less.

Plate 14.

View of the Saluda formation in the north cut of the railroad at Madison, Indiana. The overhanging bed is the heavy sandy magnesian limestone 30 feet thick, below which is 30 feet of coarse mud rock with thin limestone layers and the Columnaria reef in the middle. This mud rock rests upon the Liberty formation which is marked by the beginning of the thin limestone layers. Looking southwest.



Section of the Lower Part of the Saluda Limestone on the Southern Branch of the South Fork of Harrods Creek, 2 Miles Nearly Due North of O'Bannon.

		Ft.	Ins.
8.	Limestone, Tetradium heads on lower side, small fossils showing in section abundant in top. A loose head of Tetradium here 2½ to 3 feet in diameter, circular and shaped like a millstone	1	
7.	Shale with thin limestone laminae, gastropods	1	
6.	Limestone, hard, fine-grained, blue, argillaceous, cobbly in places	1	
5.	Shale, lower 2 to 6 inches, black, in places in contact with Columnaria heads which appear to grow up into it. Sponge bearing shale between Tetradium and Columnaria zones in Madison section? Plate 16, Section 4	1	
4.	Limestone, Columnaria heads abundant and large, growing in a layer of limestone 2 to 3 inches thick and projecting up through the shale of No. 5 to the bottom of No. 6	1	
3.	Limestone	1	6
2.	Limestone with abundant large Columnaria heads	1	
1.	Shaly material to fossiliferous Liberty formation	3-5	

The phase of the Lower Saluda exhibited in the last two sections was observed only in the locality described. Elsewhere the Columnaria reefs appear to be absent and the lower part of the Saluda, say 8 to 10 feet thick, is mostly mud rock, with a limestone layer or two and in the top of which and close beneath the 30 feet of heavy, sandy limestone, is a persistent Tetradium reef. This condition, which appears to prevail in the county, is illustrated in the sections southeast of Fern Creek and southeast of Avoca School. (Plate 16, Sections 1 and 2.) This division of the Saluda carries a good many fossils which are listed on a succeeding page.

The middle and main division of the Saluda, constituting, in Jefferson County, about two-thirds of its total thickness, is a thick-bedded, sandy, and highly magnesian limestone about 30 feet thick. It contains about 45% of calcium carbonate, 31% magnesium carbonate, and 16% silica, largely in the form of clastic quartz. (See analysis No. G3649.) Its general character is shown on Plate 17. It is thick-bedded, very fine grained, and greenish-grey in the unweathered condition. The calcareous con-

tent is great enough to produce brisk effervescence on treatment with acid. A thin section shows fairly abundant small quartz grains in a calcareous matrix. It is estimated that the quartz grains make up about 5% of the rock. The rock is rather soft and on account of its homogenity works freely into dimension stone, which if properly laid would probably have a fair degree of durability. Some of its layers show a network of sun cracks, some of which are illustrated on Plate 18. This feature shows that the beds were deposited on a muddy flat, exposed to sun and drying out at times as may be observed at the present day in areas subject to occasional overflow and the deposition of a layer of mud.

Other features worthy of mention are the color banding and, in the unweathered bed, the invisible lamination. On long continued weathering this part of the Saluda turns brown; with less thorough weathering the edges of the thick layers are thinly banded with brown, pink, yellow, and gray colors as shown on Plate 19.

The lamination and the relatively soft character of the limestone causes it to wear away in ravines beneath the cap of more compact Brassfield limestone and form falls, as shown in Plate 20. The presence of the invisible lamination cleavage in the thick layers is revealed on weathering, for these layers then split up into thin shaly laminae. This character of the rock is a serious detriment to its quality as a building stone, which can, however, be partly overcome by laying the rock with its laminae horizontal as it lies in the natural layers. All the features of this heavy bedded, sandy, magnesian limestone as described above persist uniformly from Madison, Indiana, and some distance north of that place southward through Jefferson County and an unknown distance farther south. It is about the most distinctly characterized stratigraphic unit in the geologic section of the whole region.

Plate 17.
Sandy Saluda limestone. Quarry 1 mile west of Seatonsville. Looking west.

Plate 18.
Sun (shrinkage) cracks in Saluda limestone. East branch of South Fork of Harrods Creek 2½ miles northeast of O'Bannon. These cracks show that the Saluda sediment was deposited in shallow water which dried up at times and exposed the muddy bottom to drying, shrinkage, and consequent cracking, a phenomenon of common occurrence and frequently observed at the present day.

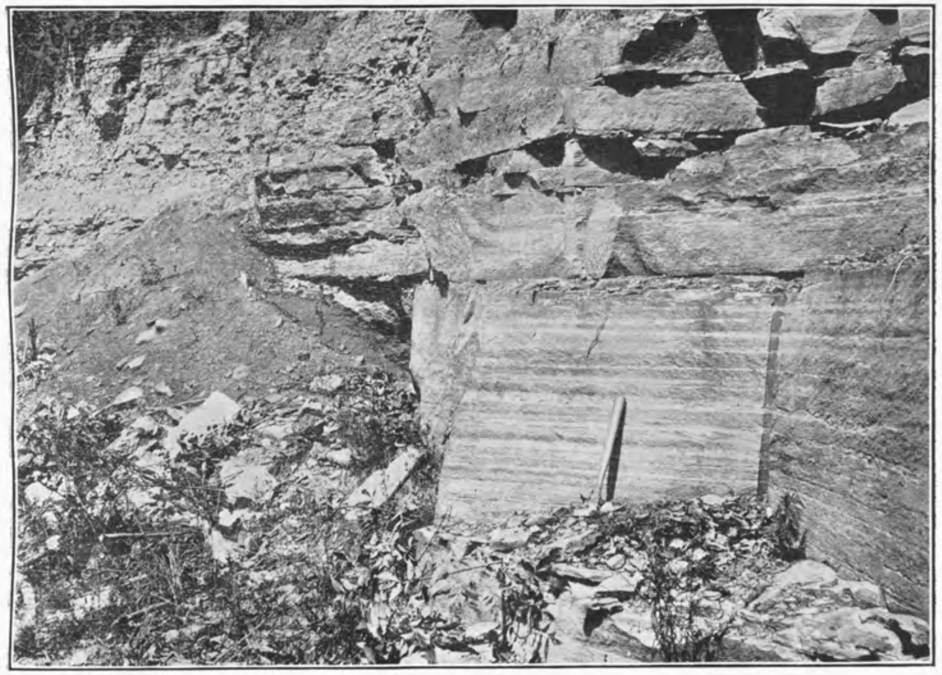


Plate 19.

Saluda limestone showing color banding in the lower right hand corner and the splitting, on weathering, of the thick beds into thin shaly laminae in the upper left hand corner.

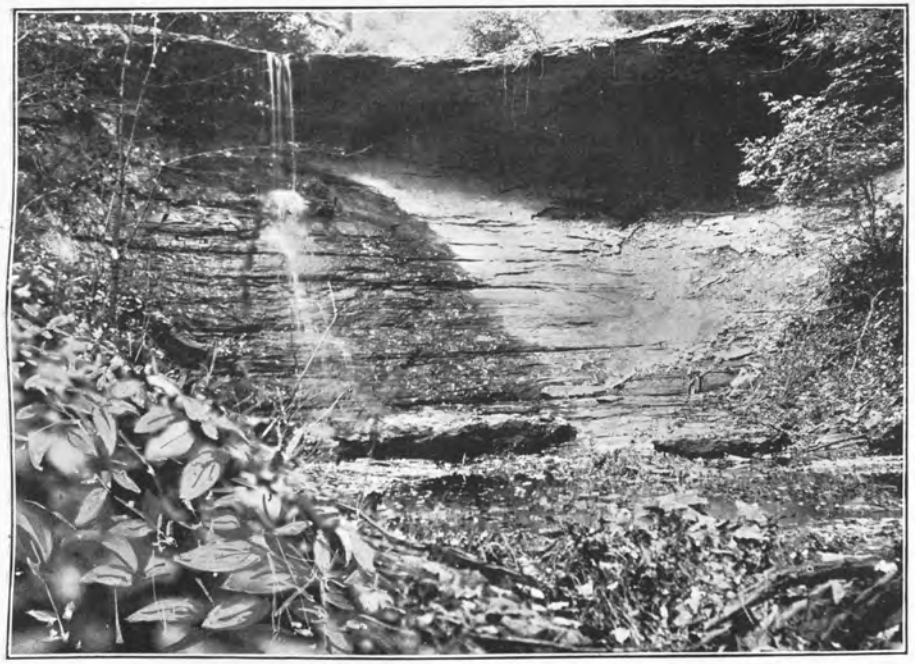


Plate 20.

Falls in a ravine 2½ miles south southeast of Fern Creek Station. The overhanging rock at the top is Brassfield beneath which is the Saluda sandy limestone that shells off across the bedding undermining the Brassfield.

HITZ LIMESTONE MEMBER OF SALUDA LIMESTONE.

NAME AND DEFINITION.—The name Hitz was applied to this member by Foerste,* his designation being Hitz bed, from Hitz Hill, in the vicinity of Madison, Indiana, in which the member is well developed and exposed. It was originally designed by Foerste† the *Murchisonia hammelli* bed, from the abundance of that fossil. In the regions where the Hitz member is distinguished it includes a thin limestone ranging up to 6 feet in thickness, occupying the space between the heavy sandy limestone of the Saluda below and the Brassfield limestone above.

DISTRIBUTION.—The Hitz limestone was observed only on the ridge between Long Run and Floyds Fork, in the vicinity of Jeffersontown and Tucker, and on Harrods Creek in the northeast part of the county. It is known to be absent at a number of points south of Fern Creek and Seatonsville, at which its horizon is exposed, but its exact southern limits between Jeffersontown and Seatonsville have not been determined. It appears to be confined to the northeast third of the county.

THICKNESS.—Where present in this region, as generally elsewhere, the Hitz member is about 5 to 6 feet thick.

CHARACTER.—The Hitz member is composed of dense, fine-grained dark-gray limestone in layers 6 inches to one foot thick. It has economic importance as a source of road metal, for which it is well suited. It is, however, of value only where it outcrops under favorable conditions for quarrying, and where thicker deposits of suitable limestone are not near.

FOSSILS OF SALUDA LIMESTONE.

The part of the Saluda below the Hitz member is very scantily fossiliferous in this county. An occasional specimen of *Hebertella sinuata* occurs. A single specimen of *Strophomena sulcata*, a characteristic Lower Saluda form elsewhere, was found 1 mile west of Seatonsville. Specimens of bryozoans also occur rarely. *Tetra-*

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*Foerste, A. F., Am. Geol., vol. 31, No. 6, p. 347, 1903.

†Foreste, A. F., Ind. Dept. Geol. & Nat. Res., 21st Ann. Rept., pp. 218-222, 1896.

dium approximatum is common just below the heavy, sandy limestone member throughout the county. On the South Fork of Harrods Creek 2 miles north of O'Bannon, and just east of the county, fossils are more abundant in limestone layers in the few feet of mudrock forming the base of Saluda. Here were obtained the fossils of list No. 1 below.

The Hitz limestone member is highly fossiliferous. Ostracods are plentiful everywhere and locally species of Ctenodonta, Lophospira and bryozoa are abundant.

The forms collected in the Saluda are listed below.

List of Fossils from the Saluda Limestone.

1.

Below the Hitz limestone member, namely, from the basal 5-10 feet of mudrock and limestone.

Corals.
- Columnaria alveolata. Goldfuss.
- Streptelasma rusticum, Billings, rare.
- Tetradium approximatum. Ulrich.

Brachiopods.
- Hebertell occidentalis sinuata. (Hall.)
- Platystrophia sp.
- Strophomena sulcata. (Verneuil.)

Pelecypods.
- Pterinea small sp.

Gastropods.
- Bellerophon mohri. Miller.
- Lophospira bowdeni. (Safford.)
- Trochonema sp.?
- Raphistoma sp.?

Ostracods.
- Eurychilina? striatomarginata. (Miller.)
- Leperditella glabra. (Ulrich.)
- Leperditia cæcigena. Miller.

2.

Hitz limestone member.

Streptelasma divaricans. (Nicholson.)

Corals.

Brachiopods.
- Hebertella occidentalis sinuata. (Hall.)

Pelecypods.
- Byssonychia sp.
- Ctenodonta? hilli. (Miller.)
- Ctenodonta sp.

Gastropods.
- Holopea hubbardi. Miller.
- Lophospira hammelli. (Miller.)

Cephalopods.
- Cyrtocerina madisonense. (Miller.)
- Dawsonoceras hammelli. (Miller.)
- Orthoceras (Ortnoceras?) hitzi. Foerste.

Ostracods.
- Eurychilina? striatomarginata. (Miller.)
- Isochilina subnodosa, Ulrich, var.
- Leperditella glabra. (Ulrich.)
- Leperditia cæcigena. Miller.

Illustrations of the more common and characteristic of these fossils are given on Plates 15 and 23.

AGE AND CORRELATION OF SALUDA LIMESTONE.

The correlation of the Saluda northward to a point some distance north of Madison, Indiana, is perfectly clear. Farther north, however, the heavy bed so persistent southward begins to split up into shale and limestone layers similar to the underlying Liberty formation, and still farther north the typical Saluda practically disappears, and in the vicinity of Richmond, Indiana, its stratigraphic interval is occupied by the typical Whitewater beds of Nickles and Cummings. The Tetradium reef below the sandy limestone is believed to persist northward to Richmond where it, or at least a Tetradium zone believed to be the same, lies at the base of what Nickles and Cummings have called Whitewater beds. Whether any part of the Saluda is represented by any part of the Elkhorn beds of Cummings recognized as forming the upper division of the Richmond at Richmond, Indiana, is not known. The Hitz limestone is the youngest member of the Richmond group in this area. It is easily recognizable as far north as Madison, Indiana, but it does not appear from descriptions to be a recognizable member far north of Madison. It possibly merges into the lower part of the higher beds of the Richmond group in the vicinity of Richmond, Indiana, which have been designated Elkhorn beds by Cummings.

AGE AND SYSTEMIC RELATIONS OF THE RICHMOND GROUP.

The Richmond group has hitherto been and in this report is assigned to the Ordovician system. The Richmond has, however, been proven to be in part or whole, of the same age as the Queenston ("red Medina") shale of New York. The proof of the correlation of the Richmond and Queenston is as follows: On Manitoulin Island in Lake Huron are beds of the Richmond type carrying typical Richmond fossils in abundance. These beds traced southeastward pass into the red Queenston shale, and at Collingwood, about midway between Manitoulin Island and Niagara Falls and about 115 miles northwest of the latter locality, Richmond fossils occur in layers interbedded with red shale. The proof seems to be conclusive. The Queenston ("red Medina") has usually been regarded as Silurian in age and it is a question whether the Richmond should not be also classed as Silurian. Ulrich* in a recent paper has discussed the subject of the age of the Richmond and set forth other reasons, besides its relations to the Queenston, for its Silurian age, chief among which are its unconformable relations to the ununderlying formations throughout the Mississippi Valley, and the change of fossils in passing from the Ordovician-Maysville group into the Arnheim formation in the Ohio, Indiana and Kentucky regions. According to Ulrich, out of 400 species in the Maysville group, only about 20 species pass upward into the Richmond, a fact which is believed to indicate that a considerable time and a great change of conditions elapsed between the deposition of the Maysville and that of the Arnheim which is the basal formation of the Richmond. The existence of this break is further confirmed by the absence westward of Nickles's Mount Auburn and Corryville beds, which are the upper two divisions of the Maysville group at Cincinnati; so that at Madison, Indiana, and at Sulphur, Kentucky; for example, the Arnheim rests on Nickles's Bellevue beds, which is the third division below the top of the Maysville group at Cincinnati. At still greater distances from the

*Ulrich, E. O., Ordovician-Silurian boundary: International Geological Congress, 12th, 1913, issued 1914.

Cincinnati region the break between the earliest Richmond stratum and the rocks upon which it rests is still greater, for the Maysville and Eden groups, which underlie the Richmond at Cincinnati, are absent, and in such regions the Richmond rests upon rocks as old as Black River. The Richmond was unquestionably laid down in a time of widespread continental subsidence and consequent extension of seas over the immediately preexisting dry land. Any such beginning of a new cycle of deposition is the most natural basis for systemic divisions of the strata of the earth's crust and in this case affords the strongest argument for placing the Richmond in the Silurian system.

It so happens, however, that the fossils that pass upward from the Maysville into the Richmond in the Cincinnati region are abundant in the Richmond and among its most striking forms, so that it was quite natural that the Richmond should be assigned to the Ordovician at a time before a more complete study of the Richmond fauna had shown the great break between the Maysville and Richmond faunas and before the great and wide-spread unconformity at the base of the Richmond was known.

Considering the strength of the several converging lines of evidence for the Silurian age of the Richmond, the writer is disposed to accept Ulrich's conclusion that the Richmond should be classed as Silurian instead of Ordovician.

SILURIAN SYSTEM.

OUTLINE.—The Silurian system, so far as represented in Jefferson County, is subdivided as shown in the following outline (see Columnar section, Plate 65):

Unconformity.
Louisville limestone.
Waldron shale.
Laurel dolomite.
Osgood formation.
Unconformity.
Brassfield limestone.

UNCONFORMITY BETWEEN THE SALUDA AND BRASSFIELD LIMESTONES.

After the deposition of the Hitz member of the Saluda, a period of time ensued which is not represented by rocks on the flanks of the Cincinnati dome, but is supposed to be represented in the Western Illinois and Eastern Missouri region by the Girardeau limestone and the Edgewood and Essex limestones of Savage aggregating a maximum thickness of 100 feet. Furthermore the Brassfield limestone, overlying the Hitz member or the sandy limestone of the Saluda, where the Hitz is absent, is believed to represent some thin part of the Cataract formation of Ontario, Canada, the Albion sandstone of Western New York, and the Tuscarora sandstone or its equivalent Clinch sandstone of the Appalachian Valley. Whatever part, if any, of these formations underlies the particular horizon represented by the Brassfield limestone is absent from the region of the Cincinnati dome. The Brassfield limestone therefore is separated from the strata upon which it rests by a stratigraphic break or, as more generally expressed, by an unconformity. The character of the contact between the Brassfield and the underlying strata is in places irregular, showing that there had been dry land made irregular on the surface by erosion before the deposition of the Brassfield. Such a condition is displayed in a road cut on the west bluff of Floyds Fork about $1\frac{1}{4}$ miles west-southwest of Seatonsville, a photograph of which is shown on Plate 21. Not more than one-half mile north of the latter locality a regular contact is exposed with a clay parting between the Brassfield and Saluda (see Plate 22). This seems to be the more usual condition of the contact.

BRASSFIELD LIMESTONE.

NAME AND DEFINITION.—The Brassfield limestone was so named by Foerste* from Brassfield, Madison County, Ky., near which it is well exposed. In Jefferson County the Brassfield includes the 1 to 3 feet of limestone lying between the Hitz limestone member, or where the Hitz member is absent, the sandy limestone of the Saluda below, and the lower limestone of the Osgood formation above.

DISTRIBUTION.—The Brassfield limestone outcrops in the eastern third of the county in the Floyds Fork drainage basin, along Harrods Creek, and at one point on Little Goose Creek 1 mile above the electric railroad where a very small area is exposed in the creek bed. It is exposed at many points, in fact, in nearly every ravine crossing its outcrop where owing to its resistance to wear it acts as a protecting cap to the Saluda which crumbles away beneath, forming falls. This feature is illustrated in Plate 20. One of the best and most accessible exposures is in the bed of Harrods Creek just above the electric railroad and highway bridges where it makes the extensive rock floor of the creek exposed at low water. The excellent exposures about 1 mile west of Seatonsville have already been described and illustrated (see Plate 22). There is an especially good display of bowlders from the Brassfield and of the ledges in place along the Pewee Valley road immediately northeast of the bridge across Floyds Fork 100 feet or so northeast of the county boundary. The ends of the bridge are about on the Brassfield bed and the road follows its outcrop for one-half mile northeast of the bridge. The Brassfield probably underlies all the western two-thirds of the county.

THICKNESS.—The thickness of the Brassfield is somewhat variable as might be expected from the fact of its deposition on a slightly uneven bottom due to prior erosion. The greatest thickness observed is 7 feet 2 inches in a quarry at Thixton; in this quarry the usual thickness is 4 feet 8 inches and the geater thickness stated is in a depression in the bottom. Four feet 8 inches is an unusually great thickness, for the prevailing thick-

*Foerste, A. F., The Silurian, Devonian and Irvine formations of East-Central Kentucky: Kentucky Geological Survey Bulletin No. 7, pp. 18 and 27.

Plate 21.

View showing erosional unconformity between the Brassfield and the Saluda limestones. Road on west bluff of Floyds Fork 1¼ miles west-southwest of Seatonsville. Contact marked by various objects. The difference between the Brassfield and Saluda is revealed by weathering as shown at the left of the photograph. Looking west

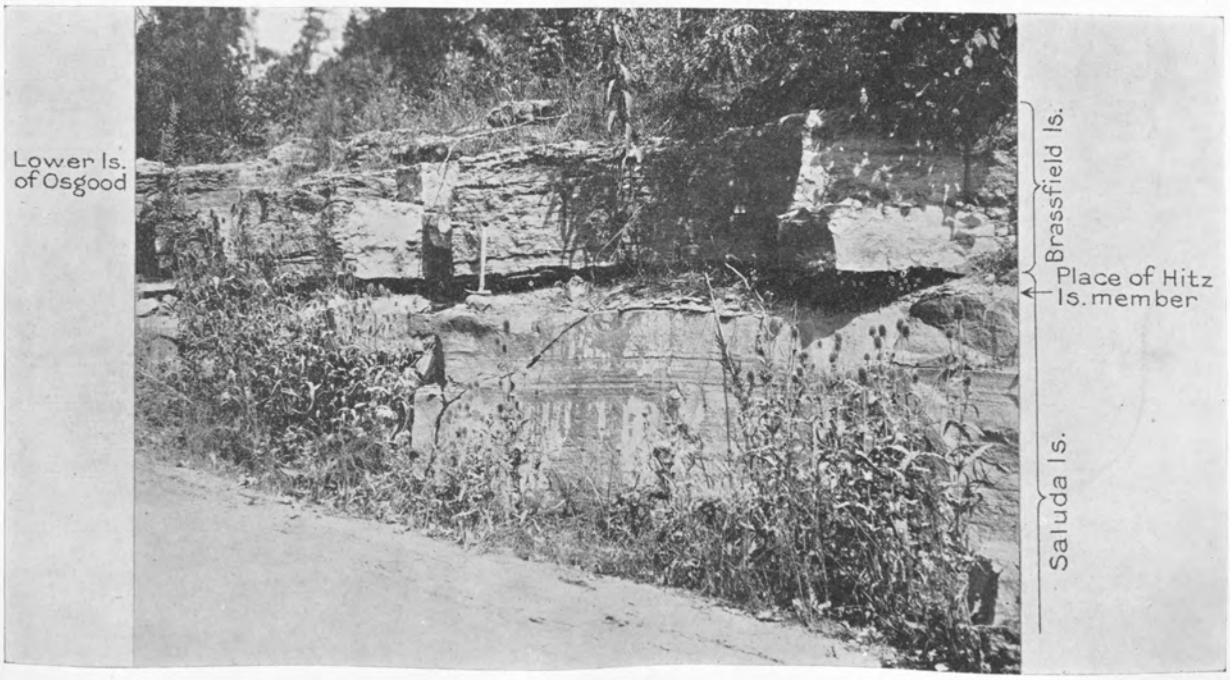

Plate 22.

Contact of Brassfield and Saluda limestones on highway on the west bluff of Floyds Fork, 1 mile west northwest of Seatonsville. Hitz limestone member absent. Looking west.

ness seems to be about $2\frac{1}{2}$ to 3 feet. In some places not well exposed there did not seem space for more than one foot of Brassfield and in a few places there is doubt whether it is present at all.

CHARACTER.—The Brassfield is a coarsely crystalline limestone in layers 6 inches thick or less. The rock is characteristically mottled white, grayish, greenish gray, salmon, brown and pink, and its recognition is easy and certain. The rock takes a good polish and owing to that fact and its soft, variegated color, would make a pleasing marble.

FOSSILS.—The bed is moderately fossiliferous, though not so rich in either species or individuals as in east Central Kentucky and in Ohio and Indiana. A list of the fossils collected in this county is given below.

List of Fossils from the Brassfield Limestone.

Corals.
- Enterolasma geometricum. Foerste.
- Favosites niagarensis. Hall.
- Favosites sp.?
- Halysites catenularia. Linnaeus.
- Heliolites interstinctus. Linnaeus.
- Stromatoporoid.
- Lindstroemia gainesi. (Davis.)
- Ptychophyllum ipomea. Davis.
- Zaphrentis celator daytonensis. Foerste.

Bryozoa.
- Clathropora frondosa clintonensis. Hall and Whitfield.
- Chasmatopora angulata. (Hall.)
- Hallopora magnopora. (Foerste.)
- Homotrypa confluens. (Foerste.)
- Pachydictya crassa. (Hall.)
- Pachydictya bifurcata. (Hall.)
- Phænopora expansa. Hall and Whitfield.
- Phænopora multifida. Hall.
- Ptilodictya expansa. (Hall and Whitfield.)
- Rhinopora verrucosa. Hall.

Brachiopods.
- Camarotœchia neglecta. (Hall.)
- Dalmanella elegantula. (Dalman.)
- Leptaena rhomboidalis. (Wilckens.)
- Orthis flabellites. Foerste.
- Platystrophia reversata. Foerste.
- Plectambonites transversus prolongatus. Foerste.
- Rhipidomella hybrida. (Sowerby.)
- Schuchertella tenuis. (Hall.)
- Strophonella striata. Hall.
- Triplecia ortoni. Meek.

Gastropods.
- Bucania sp.?
- Diaphorostoma niagarense. Hall.

Trilobites.
- Bumastus sp.?
- Calymene niagarensis. Hall.
- Encrinurus thresheri. Foerste.
- Illænus daytonensis. Foerste.

The more common and important of these forms occurring in Jefferson County are illustrated in Plate 23.

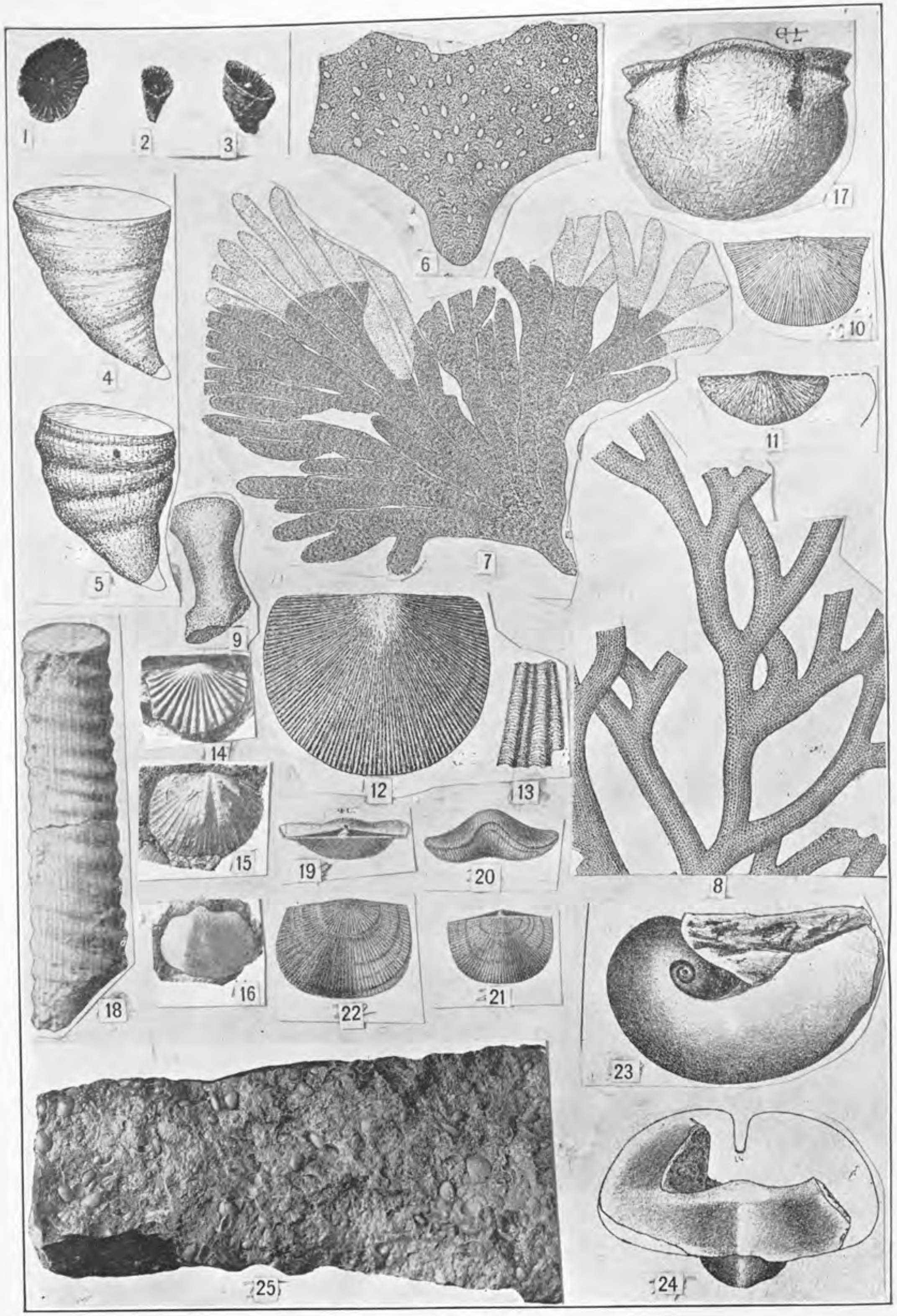

Plate 23.
Fossils of the Brassfield and Saluda limestones.

Fossils of the Saluda and Brassfield Limestones.

Plate 23.

1-3 Lindstroemia gainsei. (Davis.) After Davis. Natural size. A common cup coral in the Brassfield limestone and characteristic of it. The conical elevation in the bottom of the cup is a distinctive character of the fossil.

4-5 Zaphrentis celator daytonensis. Foerste. After Foerste. Common cup coral of the Brassfield limestone.

6 Clathropora frondosa clintonensis. Hall and Whitfield. After Foerste. Common and distinctly characterized bryozoan of the Brassfield limestone.

7 Phænopora multifida. (Van Cleve.) Hall. After Foerste. Common and characteristic bryozoan of the Brassfield limestone.

8 Pachydictya bifurcata. (Van Cleve.) Hall. After Foerste. Part of a large specimen. Brassfield limestone. Common.

9 Hallopora magnopora. (Foerste.) After Foerste. A common bryozoan. Brassfield limestone.

10 Strophonella striata. Hall. After Foerste. A common brachiopod of the Brassfield limestone. View of a brachial valve. =Strophomena (Orthototes) hanoverensis. Foerste.

11 Plectambonites transversus prolongatus. Foerste. After Foerste. A common and characteristic brachiopod of the Brassfield limestone. View of a pedicle valve and line showing convexity of the same.

12-13 Schuchertella tenuis. (Hall.) After Foerste.=Strophomena (Orthotetes) tenuis. Hall. Common large brachiopod of the Brassfield limestone. 12, view of a pedicle valve; 13, a few plications enlarged.

14-15 Orthis flabellites. Foerste. 14, exterior of valve; 15, exfoliated valve of another specimen, the usual size and condition of preservation. Brassfield limestone. Common.

16 Triplesia ortoni. Meek. Exterior of pedicle valve. Brassfield limestone only. Highly characteristic fossil but rare in Jefferson County.

17 Illænus daytonensis. Hall and Whitfield. After Foerste. Top view of head. Brassfield limestone. Common and characteristic.

Fossils of the Saluda Limestone.

18 Dawsonoceras hammelli. Foerste. After Foerste. Hitz limestone member.

19-22 Strophomena sulcata. (Vernueil.) 19, cardinal; 20, front; 21, brachial; 22, pedicle view. Base of Saluda limestone. Rare in Jefferson County.

23-24 Bellerophon mohri. Miller. After Ulrich. Base of Saluda limestone. Rare in Jefferson County.

25 Piece of limestone showing ostracods. Natural size. Hitz limestone member of Saluda. Very abundant.

AGE AND CORRELATION.—The Brassfield is the same bed as the Clinton of the earlier writings of Foerste and others on the Silurian rocks of Ohio, Kentucky and Indiana. The bed in Ohio has also been called the Ohio Clinton.

It has recently been determined by Ulrich, however, that the Brassfield is not Clinton and does not belong in the Niagara group, of which the true Clinton is a part. The Brassfield is really of the age of beds forming the upper part of the Medina group ("white Medina" of New York, which has recently been renamed the Albion sandstone,* from Albion, New York). The Albion in turn is correlated with part, at least, of the Cataract formation of Ontario, Canada† and with the Tuscarora sandstone of Pennsylvania and Maryland and the Clinch sandstone of Tennessee. Of course the Brassfield only represents a small part of the thickness of these various formations. It seems to correspond most closely with the limestone member of the Cataract formation immediately overlying the Whirlpool sandstone, which is the basal member of both the Cataract and Albion formations.

UNCONFORMITY BETWEEN THE BRASSFIELD LIMESTONE AND OSGOOD FORMATION.

The Osgood formation, overlying the Brassfield limestone, is correlated by Ulrich and Foerste with the Rochester shale member of the Clinton of New York. Assuming the correctness of this correlation, the upper part of the Albion sandstone and the lower part of the Clinton formation are unrepresented by deposits in the region of the Cincinnati dome, so that between the Brassfield and Osgood there is an unconformity spanning a considerable thickness of rock elsewhere.

*Kindle, E. M., Geol. Atlas U. S. Niagara Folio No. 190, 1913.

†Schuchert, Charles, Bull. Geol. Soc. America.

ROCKS OF NIAGARAN AGE.

In Jefferson County the rocks of Niagaran age include the Osgood formation, Laurel dolomite, Waldron shale, and Louisville limestone. These formations are predominantly limestone and dolomite and all are calcareous. Their combined thickness varies from about 120 to 180 feet, the greatest variation being in the Louisville limestone.

OSGOOD FORMATION.

NAME AND DEFINITION.—The Osgood formation was named by Foerste* from Osgood, Indiana, where there is a good development and exposure of the beds. The formation includes the beds between the well defined Brassfeld limestone below and the equally well defined base of the Laurel dolomite above.

DISTRIBUTION.—East of Floyds Fork the Osgood formation outcrops in a good sized area at the northeast boundary of the county, and in four small areas near the southern boundary. West of Floyds Fork it outcrops in an irregular band extending across the county, passing near Tucker, Jeffersontown and Thixton. It outcrops just above the creek all along Harrods Creek and in a very small area on Little Goose Creek about one mile south of Harrods Creek P. O., and on Goose Creek about 1 mile farther south. Especially good exposures of parts of the formation exist at Thixton, on the road to the east from the Bardstown pike 1 mile north of Fairmont Church, in the ravine 3/4 mile east of Bardstown pike, 2 1/2 miles southeast of Fern Creek and on the ridge 200 yards east of the road 1 mile southwest of Flat Rock School. The general aspect of the two upper members of the formation is shown on Plate 24.

THICKNESS.—The Osgood varies somewhat in thickness in this county, the maximum and prevailing thickness being about 30 feet. In a section exposed in the bank of Harrods Creek under the electric railroad bridge, however, the lower shale is only about 10 feet thick, and the whole formation probably does not exceed 22 feet.

**Foerste, A. F., Ind. Dept. Geol & Nat. Res., 22d Ann. Rept., p. 227, 1897.

The upper shale and perhaps the upper 2 or 3 feet of the upper limestone are not exposed at this point.

CHARACTER.—The Osgood formation is composed of shale and limestone in four separate divisions, which are remarkably persistent in thickness and lithic character (see sections, Nos. 1 and 2, Plate 16). At the bottom is a reddish fine-grained limestone about 2 feet thick that is present in every section exposing its horizon. In its general appearance and without close inspection it simulates the underlying Brassfield limestone. It is, however, of much finer grain, more reddish, and so far as observed without fossils, all being characters which differentiate the layer from the Brassfield with which it is in contact, but from which it is apparently separated by stratigraphic hiatus of considerable magnitude. Foerste* has noted this layer in Indiana and did not apparently include it in the Osgood, but did, however, distinctly refer it to the Niagara group, calling it the basal Niagara limestone. From its lithic resemblance to the upper limestone of the Osgood presently to be described, it seems to be properly included with the latter in the Osgood.

The lower shale of the Osgood makes up about two-thirds of the thickness of the formation. It is mostly a coarse, lumpy, gray, calcareous, and magnesian shale or mud rock. Its main constituents are silica 48%, alumina 18%, calcium carbonate 12%, magnesian carbonate 11%, potassium oxide (potash) 5.50%=95.52%. The complete analysis No. G.3651, is given in the table. The shale weathers to clay which makes white banks beneath the projecting outcrop of the upper limestone. The thickness varies from 12 to 20 feet. A few fossils occur at the top, but the lower part of the member is practically barren of fossils.

The clayey character of this shale makes its top a water table and springs are common at the outcrop of its contact with the overlying upper limestone. (See Plate 64.) It is probable, too, that it is the water-bearing stratum in many wells in the central part of the county.

The upper limestone of the Osgood is divided into layers from one foot in thickness down. It is mostly fine grained and reddish in color. There is in some sec-

*Foerste, A. F., Ind. Dept. Geol. & Nat. Res., 21st Ann. Rept., p. 226, 1896.

Plate 24.
Upper limestone and upper shale of the Osgood formation overlain by the bottom layers of the Laurel dolomite. Road to Floyds Fork leaving the Bardstown pike 1 mile north of Fairmount church. Short distance east of intersection. Looking north.

Plate 25.
Quarry in Laurel dolomite at Tucker showing the upper evenly bedded part of the Laurel which is quarried for building stone. Looking north.

tions a little coarsely crystalline, salmon colored rock which can hardly be distinguished from the Brassfield limestone, but generally the two strata are easily distinguishable. The bed is strongly magnesian, its main constituents being calcium carbonate 52.70% and magnesian carbonate 34.65%, the two substances making 87.35% of its mass. For the complete analyses see No. G-3652 of the table. The upper limestone is sparingly fossiliferous in Jefferson County. This bed is persistent throughout the county, with a thickness ranging from 5 to 8 feet.

The upper shale of the Osgood is a thin, but persistent bed present in every section exposing its horizon. It is a rather soft, somewhat coarse, fairly fissile, greenish-grey shale, composed largely of calcium and magnesium carbonates, of which it contains 37.85 per cent. of the first, and 27.70 per cent. of the last, a total for the two of 65.55. Its silica content is 21.56 per cent., and alumina 8.44 per cent., totaling 30 per cent. The complete analysis is given in No. G.3653 of the table. The thickness is 2 to 3 feet. The upper shale and limestone are illustrated in Plate 24.

The Osgood as a whole, as well as its thin divisions, is remarkably persistent in character. It extends from Tennessee to Southeastern Indiana, and the section at Madison, Indiana, has the same subdivisions as that in Jefferson County, although its thickness at Madison falls short of its maximum thickness here.

FOSSILS.—The Osgood is very sparingly fossiliferous in this region. A few individuals and species were obtained from the upper limestone and a very few, including cystids, and an orthoceras, were obtained from the lower shale. These are listed below:

List of Fossils from the Osgood Formation.

Corals.
- Enterolasma caliculum. Hall.
- Favosites cristatus. Edwards and Haime.
- Striatopora sp.?

Crinoids.
- Eucalyptocrinus cœlatus? Hall.
- Holocystites cf. parvulus. Miller.
- Stephanocrinus gemmiformis. Hall.

Bryozoa.
- Hallopora elegantula. (Hall.)
- Pachydictya crassa. (Hall.)

Brachiopods.
- Atrypa reticularis. Linnaeus.
- Dalmanella elegantula. (Hall.)
- Leptæna rhomboidalis. Wilckens.
- Orthis flabellites. Foerste.
- Plectambonites transversalis. Wahlenberg.
- Rhipidomella hybrida. Sowerby.
- Rhynchotrema cuneata americana. Hall.
- Spirifer niagarensis. Conrad.
- Spirifer radiatus. Sowerby.

Gastropods.
- Diaphorostoma niagarensis. Hall.

Cephalopods.
- Dawsonoceras annulatum. (Sowerby.)

Trilobites.
- Calymene niagarensis. Hall.

A few of the Osgood fossils are illustrated on Plates 29 and 31.

AGE AND CORRELATION.—The Osgood as a whole is correlated with the Rochester shale member of the Clinton of New York, by both Foerste and Ulrich. This correlation appears to be based partly upon the stratigraphic relations of the formation and upon its faunal contents and partly upon faunal evidence of negative character. In more detail the points in the evidence seem to be about as follows:

The Osgood overlies the Brassfield, which, as has been already stated, is of Medina age. The total absence

of earlier Clinton fossils in or below the Osgood is negative evidence that the earlier Clinton is not present. The Laurel dolomite, which overlies the Osgood, is correlated both on paleontologic and lithologic grounds with the lower part of the Lockport dolomite, which immediately overlies the Rochester shale of Western New York. Therefore the Osgood, which lies above the horizon of the earlier Clinton of Western New York and below the Laurel dolomite, is the same as the Rochester shale, which in Western New York forms the top member of the Clinton and underlies the Lockport dolomite. This conclusion is corroborated by the occurrence in the Osgood of Indiana and Tennessee of a few fossils identical with forms occurring in the Rochester shale, such as the characteristic Rochester forms *Caryocrinus ornatus* and *Dalmanites limulurus*. The genus *Spirifer* begins in Indiana in the Osgood and in New York possibly in the earlier Clinton, but becomes common only in the Rochester member. *Spirifer niagarensis* and *Spirifer crispus* apparently first appear in the Rochester shale as they do in the Osgood. *Spirifer radiatus,* although beginning in the earlier Clinton, is common to the Rochester and Osgood. The genus *Stephanocrinus* also appears to begin in the Rochester and Osgood and does not extend much above those horizons.

The lower limestone of the Osgood appears to lie near the horizon of the Dayton limestone of Ohio and Foerste's Oldham limestone of Kentucky east of the Cincinnati dome, and the remainder of the Osgood perhaps represents Foerste's Estill clay of Eastern Central Kentucky and the shale in Ohio which overlies the Dayton limestone. Foerste's Lulbegrud clay and Waco limestone of the East Central Kentucky section appear to be absent west of the Cincinnati dome, where their horizon appears to lie between the lower limestone and the lower shale of the Osgood, since their position in East Central Kentucky is between the Foerste's Oldham limestone and Estill clay, which may represent the lower limestone and the lower shale of the Osgood respectively.*

*See Foerste. The Silurian, Devonian and Irvine Formations of East Central Kentucky. Kentucky Geological Survey, Bulletin No. 7, pp. 27-63, 1906.

LAUREL DOLOMITE.

NAME AND DEFINITION.—The name Laurel was applied to the stratum here described by Foerste* from the town of Laurel, Franklin County, Indiana, where the bed is quarried. Foerste's first designation was Laurel bed. Later he changed it to Laurel limestone, and the writer has changed the name to Laurel dolomite since the stratum has essentially the composition of dolomite. The stratum extends vertically from the top of the upper shale of the Osgood below to the bottom of the Waldron shale above.

DISTRIBUTION.—The Laurel dolomite outcrops along the ridges and spurs and westward into the valleys on the west of Floyds Fork, passing through Tucker, Jeffersontown and Thixton. East of Floyds Fork, there is a small area on the northeast side of the county, and three small areas on the south side. From its eastern outcrop it extends beneath the highland and outcrops near the stream beds along Hites, Harrods, Little Goose and Goose Creeks. Its outcrop, one-fourth mile wide, extends northeast from Harrods Creek to the vicinity of Prospect. On the south side of the county it outcrops along the banks and in the beds of Pennsylvania Run and Cedar Creek. Among the best exposures is one in a small ravine one-half mile northeast of Harrods Creek station and another in the quarry at Tucker. It is also well exposed along the roads and ravines southwest of Fairmont church.

THICKNESS.—The Laurel dolomite in this county ranges from 35 to 40 feet in thickness. Possibly it slightly exceeds 40 feet in the northeast part of the county.

CHARACTER.—The analyses of this rock show it to contain over 30 per cent. of magnesium carbonate. (See table of analyses, Nos. G.3635-3642.) Approximately it is composed of calcium carbonate 58%, magnesium carbonate 33%, and silica 6.5% with small amounts of alumina and iron oxide. Some layers contain some calcite filling small cavities. The upper part is evenly bedded and compact, the layers being about 1 foot thick and

*Foerste, A. F., Cin. Soc. Nat. Hist. Journal, vol. XVIII., Nos. 3 and 4, p. 190, 1896.

quarrying out in convenient blocks for reducing to building stone; in the lower half of the stratum the layers appear to be somewhat less even and less compact and they break across less smoothly. These contrasted features are exhibited on Plate 25.

In places about 10 feet above the bottom is a massive layer several feet thick which outcrops as a ledge and which weathers with a rough cavernous surface, giving it a characteristic appearance. It is conspicuous on Little Goose Creek about one mile above the trolley line and elsewhere. The texture of the Laurel is medium fine grained throughout and the color in the fresh condition is bluish gray in the lower part and a rather light gray in the upper part. On weathering the rock assumes a buff or brownish gray tone.

FOSSILS.—The Laurel is very poor in fossils in this region and seems to be so generally throughout its extent. Below are lists of those collected in Jefferson County and in other regions, the latter being made up from Foerste's descriptions, mainly in Indiana.

List of Fossils from the Laurel Dolomite in Jefferson County, Kentucky.

Corals.
- Striatopora gorbyi. Miller.

Crinoids.
- Crinoidal joints abundant in a few layers.

Brachiopods.
- Atrypa reticularis. Linnaeus.
- Dalmanella elegantula. Hall.
- Spirifer sp.?

Trilobites.
- Dalmanites limulurus. Green.

List of Fossils from the Laurel Dolomite in Other Regions, Particularly Southeastern Indiana. Taken from Foerste.*

Calymmene niagarensis. Hall.
Dalmanites limulurus. Green.
Pisocrinus benedicti. Miller.
Pisocrinus gemmiformis. Miller.
Pentamerus (oblongus)? Sowerby.

*Foerste, A. F., A report on the Geology of the Middle and Upper Silurian rocks of Clark, Jefferson, Ripley, Jennings and Southern Decatur Counties.

AGE AND CORRELATION.—The meager fauna listed is hardly adequate evidence for the correlation of the Laurel. The *Calymmene* and *Dalmanites,* however, point to its close connection with the Rochester shale. The *Dalmanites* especially is a good Rochester guide fossil. In Western New York the lower part of the Lockport dolmite also contains a more considerable number of species that lived in Rochester time.

As already shown, the Osgood formation is correlated with the Rochester shale; and the Laurel, which overlies the Osgood and is highly magnesian, may, with reason, on the ground of its fossils, its lithic composition, and its stratigraphic position, be correlated with the lower part of the Lockport dolomite of New York.

WALDRON SHALE.

NAME AND DEFINITION.—The Waldron shale takes its name from Waldron, Shelby County, Indiana, a locality famous for the abundance and perfection of the fossils of the formation. The name was first applied by Elrod.*

The Waldron in Jefferson County includes the 10 to 15 feet of shaly rock lying between the Laurel dolomite below and the Louisville limestone above, as shown on Plate 26.

DISTRIBUTION.—The Waldron shale outcrops along a narrow band following a very irregular course across the county roughly about one-third of the distance from the eastern boundary to Louisville. It crosses the Shelbyville trolley line at English Station, 1 mile east of Middletown, passes through Jeffersontown just east of the main street, crosses the Bardstown Pike near Fairmont Church, and crosses the south boundary of the county at the same point as Floyds Fork. West of this continuous line of outcrop are isolated bands that have been exposed by the down-cutting of the valleys of Cedar and Pennsylvania creeks on the south, of Hite, Harrods, and Little Goose Creeks on the north, and of the deepest two ravines southwest of Goose Creek, the westernmost being about 1 mile east of Callahans. It is possibie, also,

*Elrod, M. N., Ind. Dept. of Geol. & Nat. Hist., 12th Ann. Rept., p. 111, 1882.

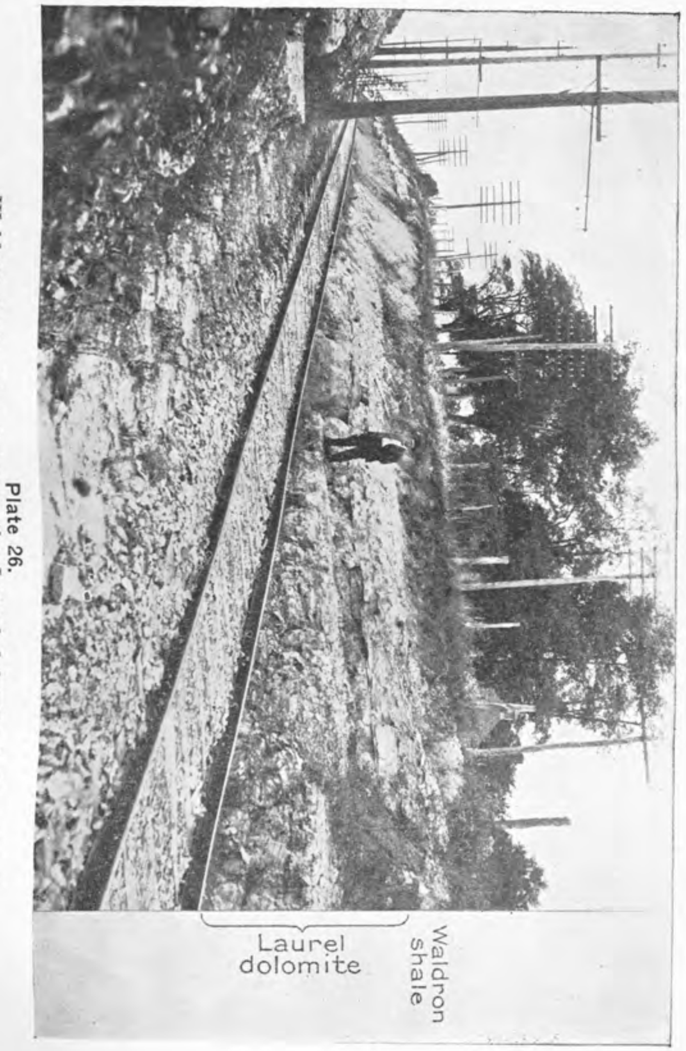

Plate 26.
Waldron shale lying between the Laurel dolomite below and the Louisville limestone above. Cut in the Shelbyville electric railroad just east of English station 1 mile east of Middletown. Looking west.

that the middle fork of Beargrass Creek north of Cave Hill Cemetery has cut down to the Waldron, although, owing to lack of exposure of bed rock at creek level, it is not possible to decide that point. As shown by a well-boring the Waldron is present 90 feet below the surface near Buechel. The bed is present also at Zoneton on the Preston Street Turnpike 1¼ miles south of the county. It evidently extends westward to the middle line of the county, beyond which knowledge of it is wanting.

The best exposure of the Waldron is that in the railroad cut at English shown in Plate 26. It shows as a clay at several points on the road from Fern Creek to Seatonsville and there is a good exposure in the road on the west bank of Cedar Creek, at the south boundary of the county. In fact the Waldron is exposed as a shale or clay lying between two limestones at so many points where its outcrop is crossed by roads and ravines and also as clay banks in fields that it is hardly necessary to specify particular exposures.

THICKNESS.—The thickness of the Waldron is very constant and does not vary much from 12 feet throughout the county, although it may be locally as little as 8 feet.

CHARACTER.—As determined by a single analysis, the Waldron shale has the following approximate composition: silica 29%; alumina 13%; iron oxide 3%; calcium carbonate 27%; magnesium carbonate 22%; potassium oxide 3%, and sulphur trioxide 3%. The sample analyzed was collected from a fairly fresh exposure at English Station, 1 mile east of Middletown, and represents an average of the upper 8 feet of the formation. It is therefore a highly calcareous and magnesian shale and evidently originated under conditions closely similar to those under which the other Niagaran formations were accumulated.

The shale is greenish gray in color, coarse textured, fragile, non-fissile, cleaving or breaking into irregular lumps or pieces. On weathering it disintegrates readily into a greenish clay. On less complete weathering it becomes a soft, laminated rock locally called "soapstone," a condition that it presents where exposed in stream banks, kept wet and constantly worn away on the surface.

FOSSILS.—At some localities as Waldron, Indiana, and Newsom, Tennessee, the Waldron is highly fossili-

ferous, but it is not so in this part of Kentucky. At the former localities are many species represented by many perfectly preserved individuals. In Kentucky, however, only a few fossils have been discovered, although diligent search has been made. The few collected in the course of the present survey are listed below.

List of Fossils from the Waldron Shale.

Bryozoa.
- Dictyonema sp.?
- Pachydictya crassa. (Hall.)

Brachiopods.
- Atrypa reticularis. Linnaeus.
- Camaratœchia? acinus. Hall.
- Camaratœchia? neglecta. Hall.
- Dalmanella elegantula. (Hall.)
- Rhynchotreta cuneata americana. Hall.
- Spirifer crispus simplex. Hall.
- Spirifer radiatus. Sowerby.

Trilobites.
- Calymene sp.?

This list contrasts strongly with the list of about 112 species described by Hall* from Waldron, Indiana, and the list of species collected by Foerste† at a single exposure at Newsom, Tennessee.

AGE AND CORRELATION.—The Waldron shale is faunally closely connected with the Niagara formations of New York, and if the correlation of the Laurel dolomite with the lower part of the Lockport dolomite is correct, the Waldron represents a stratigraphic level either in the Lockport, somewhat higher than that represented by the Laurel or a level above the Lockport. The Waldron has been identified in Indiana as far north as Rush County, where it is less than 2 feet thick, and southward it is recognized as far as Southern Tennessee, where it appears to have the same thickness as in Jefferson County. Throughout its whole known extent, a distance of nearly 300 miles, it lies, as in Jefferson County, between the Laurel dolomite below and, with local exceptions, the Louisville limestone or its equivalent above, and preserves its lithic and faunal features as well.

*Hall, Jas., Fauna of the Niagara group in Central Indiana: Twenty-eighth Ann. Rept. of the New York State Museum of Natl. Hist., 1879.
†Foerste, A. F., Silurian and Devonian limestones of Tennessee and Kentucky: Bull. Geol. Soc. Am., vol. 12, p. 442.

UNCONFORMITY BETWEEN THE WALDRON SHALE AND LOUISVILLE LIMESTONE.

According to Pate and Bassler* there intervene in Western Tennessee between the Waldron and the Lobelville shaly limestone member (in the top of the Brownsport formation), which on paleontologic evidence appears to represent the Louisville limestone in that region, the following members, named in ascending order: Lego limestone 46 feet, Dixon earthy limestone 44 feet, Beech River shaly limestone 106 feet, and Bob crystalline limestone 75 feet, in all 271 feet. The Lego and Dixon are members of the Wayne formation, and the Beech River and Bob are members of the Brownsport formation. In Jefferson County, however, the Louisville limestone follows the Waldron immediately and the Western Tennessee members named above are absent, thus leaving a stratigraphic gap or unconformity between the Waldron and Louisville. The length of time between the close of the Waldron deposition and the beginning of the Louisville deposition is thus considerable since it was sufficient to permit in the Tennessee region the deposition of 271 feet of fine shale and limestone, which accumulate relatively slowly.

LOUISVILLE LIMESTONE.

NAME AND DEFINITION.—The Louisville limestone is named from Louisville where it is of average thickness and where all of its features are typically exposed. The name was introduced by Foerste.† The formation includes the limestone mass 40 to 100 feet thick in this county, lying between the well-defined Waldron shale below and the Jeffersonville limestone, of Devonian age, above, which is very sharply differentiated from the Louisville by its totally different fauna and lithic character.

DISTRIBUTION.—The Louisville limestone has a larger area of outcrop than any other formation in the county except the older alluvial deposits along the river.

*Pate, Wm. F., and Bassler, R. S., Late Niagaran Strata of West Tennessee: Proc. U. S. Nat. Mus., vol 34, pp. 407-432, 1908.

†Foerste, A. F., Ind. Dept. Geol. & Nat. Res., 21st Ann. Rept., pp. 217 and 232, 1896.

As shown on the areal geology map, it occupies a broadly wedge-shaped area 5 miles wide in the southern half extending through the east central part of the county from southwest to northeast and forms the larger part of the valley walls of all the streams along the northwest side of the county northeast of Louisville.

THICKNESS.—The thickness of the Louisville limestone varies within the county from 42 to 100 feet. It is thinnest in the northeast corner and thickens southwestward. At Buechel it is about 90 feet thick in a well, and from the elevation of the top of the limestone and that of the Waldron shale at its base near the south boundary of the county, a thickness of not less than 100 feet is inferred in that vicinity. The measured thickness exposed in the quarries in the eastern part of Louisville is 63 feet and 5 inches, and as the bottom is not exposed it is probably somewhat thicker in that locality.

CHARACTER.—The Louisville is mostly a gray, fine-grained, thick-bedded, low magnesian limestone. Its general aspect is displayed in Plate 57. A detailed section of the formation is given under the heading Economic Geology.

The different layers of the Louisville limestone vary considerably in composition, as shown in the series of analyses in the table. The top layer, analysis G-3,617, has the maximum of silica, viz., 26.56%, due to its highly cherty character. The eighth layer below the top, analysis G-3,619, has the maximum of magnesium carbonate, 29.76%; the third layer below the top, analysis G-3,614, has 25.30% magnesium carbonate. These two layers should be classed as high magnesian limestone. The other layers vary in magnesium carbonate from 2.16% to 17.87%, and may be classed as low magnesian limestone. Excepting two layers, analysis G-3,614 and G-3,619, in which the calcium carbonate is 56.10% and 48.85% respectively, the calcium carbonate content ranges between 62.5% and 91.8%, most layers having between 70% and 80%. Except in the top layer, analysis G-3,617, the silica content varies from 3.40% to 15.90%. The alumina content equals or exceeds 3% in only 4 layers. The two high magnesian layers are distinctly different in their physical aspects from the remainder of the formation. They are finer grained, have a compact, or earthy aspect, are bluish

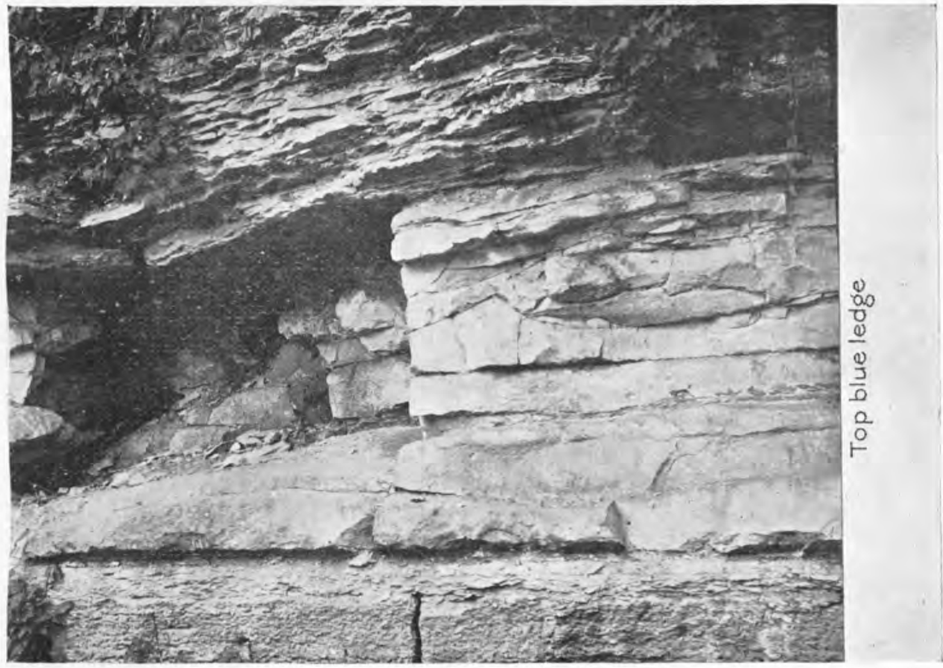

Plate 27.
Louisville limestone showing the top blue ledge. Melwood Avenue 1 mile northeast of Louisville. Looking southeast.

Plate 28
Louisville limestone in a quarry in the eastern part of Louisville showing the etching of the top layer by differential weathering along joint planes due to the presence of siliceous layers. The view also shows how etching brings out the difference between the Louisville and Jeffersonville limestones. The top 2½ to 3 feet of the layer on which the man stands, which weathers smooth, is the basal part of the Jeffersonville.

in color when fresh, but weather to a yellowish gray or buffish tone. On account of their bluish color these two layers are known to the quarrymen as "blue ledges." With one exception they are the highest in alumina and both are high in silica. On thorough weathering they take on a distinctly characteristic appearance, being of smooth surface, thick bedded, and of buff color, features that are in part brought out in the photograph, Plate 27.

The silica in the limestone is largely at least in the form of chert, some of which is dense and gray and some of chalky appearing texture and of whitish color like that in the Silver Creek limestone of the Devonian, 20 to 40 feet above the top of the Louisville. The chert is nodular or platy. The chert nodules are generally the size of the fist or smaller and irregularly arranged. The platy chert is in plates or nearly continuous layers generally 2 inches or less in thickness and arranged parallel to the bedding.

It is possible also that, beside the chert, silica in other forms and alumina, all less soluble than the finer rock, are more or less aggregated along definite planes parallel to the bedding, as a result of which the rock mass is etched in weathering, leaving the siliceous parts standing in relief on the edges of the weathered layers as irregular projections or definite linear ribs as shown on Plate 28. The etching has taken place on perpendicular joint faces, the joints having afforded downward passage to surface waters more or less charged with carbon dioxide to which the solvent power of the water is due.

FOSSILS.—The Louisville limestone is highly fossiliferous. The top layer of cherty limestone 4 to 5 feet thick and the lower 20 feet or so being the most productive. A large proportion of the fossils listed from the Louisville ("Niagara, upper white clay"), and published in such works as Kentucky Fossil Shells, by Nettelroth,* and Kentucky Fossil Corals by Davis† were obtained from this layer. The following list is taken from the two reports mentioned.

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*Nettelroth, Henry, Kentucky Fossil Shells: Kentucky Geological Survey, 1889.

†Davis, William J., Kentucky Fossil Corals: Kentucky Geological Survey, pt. II., 1885.

List of Fossils from the Louisville Limestone.

(Davis and Nettelroth.)

Spongs.
- Astræospongia meniscus. (Roemer.)
- Cyathospongia excresens. Hall.

Corals.
- Alveolites fibrosus. Davis.
- Alveolites louisvillensis. Davis.
- Alveolites thoroldensis. Parks.
- Alveolites undosus. Miller.
- Amplexus shumardi. Edwards and Haime.
- Aulopora precius. Hall.
- Aulopora pygmea. Davis.
- Aulopora vanclevi. Hall.
- Blothrophyllum niagarense. Davis.
- Blothrophyllum cinctosum. Greene.
- Calceola (Rhizophyllum) attenuatus. Lyon
- Calceola (Rhizophyllum) corniculum. Lyon.
- Chonophyllum capax. Hall.
- Chonophyllum vadum. Hall.
- Cladopora aculeata. Davis.
- Cladopora complanata. Davis.
- Cladopora equisetalis. Davis.
- Cladopora laqueata. Rominger.
- Cladopora menis. Davis.
- Cladopora ordinata. Davis.
- Cladopora proboscidalis. Davis.
- Cladopora striata. Davis.
- Cladopora reticulata. Davis.
- Cœnites crassa. Rominger.
- Cœnites laminata. Hall.
- Cœnites verticillatus. Winchell and Marcy.
- Cyathophyllum flos. Davis.
- Cyathophyllum intertrium. Hall.
- Cyathophyllum radiata. Rominger.
- Cystiphyllum gemmula. Greene.
- Cystiphyllum granilineatum. Hall.
- Cystiphyllum incurvum. Davis.
- Cystiphyllum lineatum. Davis.
- Cystiphyllum louisvillense. Greene.
- Cystiphyllum niagarense. Hall.
- Dictyostroma undulatum. Nicholson.
- Diorychopora tenuis. Davis.
- Diphyphyllum billingsi. Greene.
- Diphyphyllum huronicum. Rominger.

- Eridophyllum cruciforme. Davis.
- Eridophyllum dividum. Davis.
- Eridophyllum louisvillense. Greene.
- Eridophyllum rugosum. Edwards and Haime.
- Eridophyllum sentum. Davis.
- Favosites cristatus. Edwards and Haime.
- Favosites cristatus major. Davis.
- Favosites discus. Davis.
- Favosites favosus. Goldfuss.
- Favosites forbesi. Edwards and Haime.
- Favosites hisingeri. Edwards and Haime.
- Favosites louisvillensis. Davis.
- Favosites niagarensis. Hall.
- Favosites spinigerus. Hall.
- Hallia divisa. Hall.
- Hallia scitula. Hall.
- Halysites catenularia. Linnæus.
- Halysites labyrinthicus. Goldfuss.
- Heliolites elegans. Hall.
- Heliolites interstinctus. Linnæus.
- Heliolites megastoma. McCoy.
- Heliolites pyriformis. Guettard.
- Heliolites subtubulatus. McCoy.
- Heliophyllum dentilineatum. Hall.
- Heliophyllum flos. (Greene.)
- Heliophyllum gemmiferum. Hall.
- Heliophyllum mitellum. Hall.
- Heliophyllum parvum. Hall.
- Heliophyllum puteum. Hall.
- Lyellia americana. Edwards and Haime.
- Lyellia discoidea. Davis.
- Lyellia glabra. Owen.
- Lyellia papillata. Rominger.
- Lyellia parvituba. Rominger.
- Lyellia puella. Davis.
- Lindstrœmia? herzeri. (Hall.)
- Lophiostroma spindicandum. Parks.
- Michelinia louisvillensis. Greene.
- Michelinia niagarensis. Davis.
- Michelinia prima. Davis.
- Milleria laminata. Davis.=Dictyostroma undulatum. Nicholson.
- Omphyma verrucosa. Rafinesque and Clifford.
- Plasmopora follis. Edwards and Haime.
- Ptychophyllum benedicti. Greene.
- Ptychophyllum fulcratum. Hall.
- Ptychophyllum invaginatum. Davis.
- Ptychophyllum ipomea. Davis.

Ptychophyllum (Omphyma) stokesi. Edwards and Haime.
Romingeria uva. Davis.
Romingeria vanula. Davis.
Streptelasma conulus. Rominger.
Streptelasma patula. Rominger.
Streptelasma radicans. Hall.
Streptelasma spongiaxis. Rominger.
Striatopora huronensis. Rominger.
Strombodes incertus. Davis.
Strombodes mamillaris. Owen.
Strombodes pentagonus. Goldfuss.
Strombodes pygmeus. Rominger.
Strombodes quadrangularis. Davis.
Strombodes separatus. Ulrich.
Strombodes sinemurus. Davis.
Strombodes striatus. D'Orbigny.
Strombodes unicus. Davis.
Syringopora (Drymopora) fasicularis. Davis.
Syringopora fibrata. Rominger.
Thecia major. Rominger.
Thecia minor. Rominger.
Zaphrentis obliqua. Davis.
Zaphrentis patens. Billings.
Zaphrentis scutella. Davis.
Zaphrentis socialis. Davis.
Zaphrentis subvesicularis. Hall.
Zaphrentis umbonata. Rominger.
Zaphrentis unica. Davis.

Crinoids.
Anisocrinus greeni. Miller and Gurley.
Caryocrinites kentuckyensis. Miller and Gurley.
Macrostylocrinus meeki. Lyon.
Melocrinus oblongus. Wachsmuth and Springer.
Troostocrinus reinwardti. (Troost.)

Bryozoa.
Corynotrypa dissimilis. (Vine.)
Hallopora elegantula. (Hall.)
Pachydictya crassa. (Hall.)

Brachiopods.
Anastrophia internascens. Hall.
Anastrophia interplicata. Hall.
Anoplotheca (Leptocœlia) hemispherica. (Sowerby.)
Atrypa calvini. Nettelroth.
Atrypa marginalis. Dalman.

Atrypa nodostriata. Hall.
Atrypa reticularis niagarensis. Nettelroth.
Camarotœchia? acinus. Hall.
Camarotœchia? indianensis. Hall.
Camarotœchia? pisa. (Hall and Whitfield.)
Clorinda (Pentamerus) ventricosa. Hall.
Conchidium crassiplicata. Hall and Clarke.
Conchidium exponens. Hall and Clarke.
Conchidium knappi. (Hall and Whitfield.)
Conchidium littoni. Hall.
Conchidium nettelrothi. Hall and Clarke.
Conchidium nysius. (Hall and Whitfield.)
Conchidium tenuicostatum. (Hall and Whitfield.)
Conchidium unguiforme. Ulrich.
Cyrtia exporrecta. Wahlenberg.
Cyrtia myrtia. Billings.
Dalmanella elegantula. (Hall.)
Gypidula globulosa. Nettelroth.
Gypidula knotti. Nettelroth.
Gypidula (Sieberella) nucleus. Hall and Whitfield.
Gypidula uniplicata. Nettelroth.
Leptaena rhomboidalis. Wilckens.
Meristina maria. Hall.
Nucleospira elegans. Hall.
Nucleospira pisiformis. Hall.
Orthis flabellites. Foerste.
Orthis nettelrothi. Hall and Clarke.
Orthis? rugiplicata. Hall and Whitfield.
Orthis subnodosa. Hall.
Orthostrophia (Schizoramma) nisis. Hall and Whitfield.
Pentamerus cylindricus. Hall and Whitfield.
Pentamerus oblongus. Sowerby.
Pentamerus pergibbosus. Hall and Whitfield.
Reticularia (Spirifer) dubia. (Nettleroth.)
Rhipidomella hybrida. (Sowerby.)
Rhynchonella? bellaforma. Nettelroth.
Rhynchonella rugicosta. Nettelroth.
Rhynchospira? helena. (Nettelroth.)
Rhynchotreta cuneata americana. Hall.
Schuchertella subplanus. (Conrad.)
Schuchertella tenuis. (Hall.)
Spirifer (Delthyris) crispus simplex. (Hall.)
Spirifer (Eospirifer) eudora. (Hall.)
Spirifer (Eospirifer) foggi. (Hall.)
Spirifer (Eospirifer) radiatus. (Sowerby.)
Spirifer (Eospirifer) rostellum. (Hall and Whitfield.)
Stricklandinia? louisvillensis. Nettelroth.

Stropheodonta profunda. Hall.
Strophonella costatula. Hall and Clarke.
Strophonella striata. (Hall.)
Uncinulus stricklandi. (Sowerby.)
Uncinulus tennesseensis. (Roemer.)
Whitfieldella (Meristina) nitida. (Hall.)
Wilsonia saffordi. (Hall.)
Wilsonia saffordi depressa. (Nettelroth.)
Wilsonia wilsoni. (Sowerby.)

Gastropods.
Cœlocaulus (Murchisonia) petila. (Hall and Whitfield.)
Cyclonema cancellata. Hall.
Diaphorostoma (Platyostoma) niagarense. (Hall.)
Lophospira (Pleurotomaria) casii. (Meek and Worthen.)
Platyceras unguiforme. Hall.
Poleumita (Cyclonema) rugaelineata. (Hall and Whitfield.)
Strophostylus cancellatus. Hall.
Trochonema fatuum. Hall.

Cephalopods.
Discoceras marshi. Hall.

Trilobites.
Bumastus ioxus. Hall.
Illænus conigerus. Hall and Whitfield.

A number of the characteristic Louisville limestone fossils are shown in Plates 29, 30 and 31.

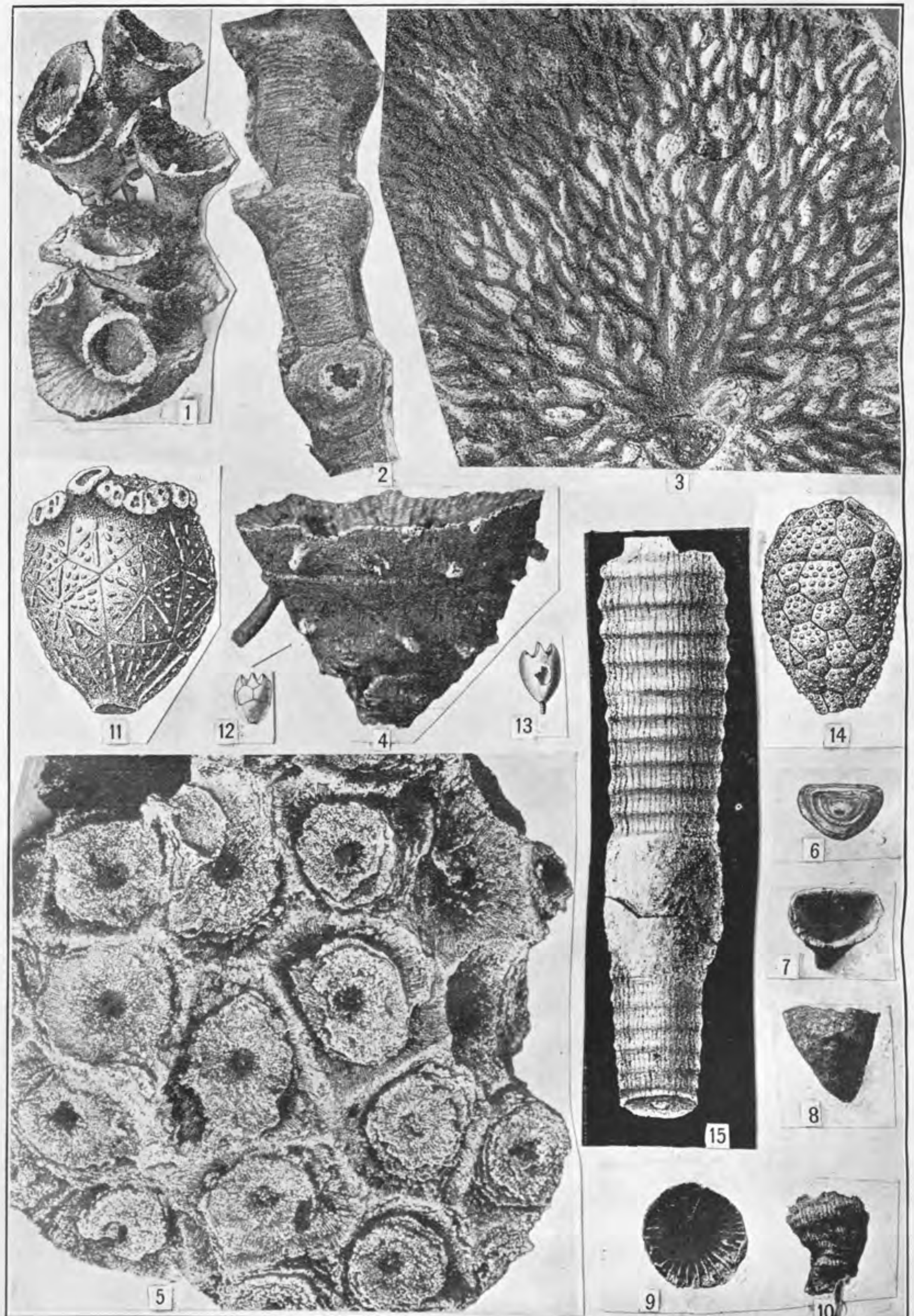

Plate 29.
Fossils from the Osgood formation and Louisville limestone.

Fossils from the Osgood Formation and Louisville Limestone.
Plate 29.

1 Ptychophyllum stokesi. Edwards and Haime. After Davis. Louisville limestone.

2 Amplexus shumardi. Edwards and Haime. After Davis. Louisville limestone.

3 Cladopora reticulata. Hall. After Davis. Rather common and characteristic coral of the Louisville limestone. Nothing resembling it in any other formation.

4 Omphyma verrucosa. Rafinesque and Clifford. After Davis. Common and characteristic coral of the Louisville limestone.

5 Strombodes striatus. D'Orbigny. After Davis. Common and characteristic coral of the Louisville limestone. There are several other species resembling this and specimens are plentiful. Any one of them is a sure index of the Louisville limestone.

6-8 Calceola attenuatus. Lyon. After Davis.=Calceola proteus. Louisville limestone.

9-10 Cyathophyllum radicula. Rominger. After Davis. Louisville limestone.

11 Caryocrinites indianensis. Miller. After Miller. This fossil or one very similar occurs in the lower layers of the Louisville limestone where separate plates or the whole base is fairly common.

12 Stephanocrinus gemmiformis. Hall. After Hall. Rare in the upper limestone of the Osgood formation. Fig. 13 shows a few segments of the jointed stalk.

14 Holocystites parvulus. Miller. After Miller. This or a very similar form occurs in the lower shale of the Osgood formation where, however, it is very rare. The Osgood has several species of Holocystites which seem to be confined to that formation.

15 Dawsonoceras annulatum. Sowerby. After Clarke and Ruedemann. Rare but characteristic fossil of the Osgood formation in Jefferson County.

Corals of the Louisville Limestone.
Plate 30.

1-2 Heliolites interstinctus. Linnæus. After Davis. 1, top view; 2, basal view. Common coral of the Louisville limestone. Occurs also rarely in the Brassfield limestone.

3 Heliolites megastoma. McCoy. After Davis. Shows the openings of the small tubes between those of the large ones. Louisville limestone.

4 Lyellia papillata. Rominger. After Davis. Resembles Heliolites in general aspect but the openings of the large cells have a raised border. Louisville limestone.

5 Plasmopora follis. Edwards and Haime. After Davis. Characteristic coral of the Louisville limestone.

6 Thecia major. Rominger. After Davis. Common coral characteristic of the Louisville limestone.

7-8 Favosites favosus. Goldfuss. After Davis. Honeycomb coral. Louisville limestone. Many other species of Favosites in the Louisville and Jeffersonville limestone. This form can be identified by the large size of the cells.

9 Favosites forbesi. Edwards and Haime. After Davis. Louisville limestone only, fairly common form. Has a short thick stalk-like lower part with an expanded head like a toadstool.

10 Halysites catenularia. Linnæus. (Chain coral.) After Davis. Abundant in the Louisville limestone, rare in the Brassfield limestone. This form is common to abundant to the very top of the Louisville limestone where it may be found in layers immediately in contact with overlying layers containing the large cup corals characteristic of the Devonian limestone. Since the Halysites can be recognized without difficulty it can be used for identifying the Louisville limestone.

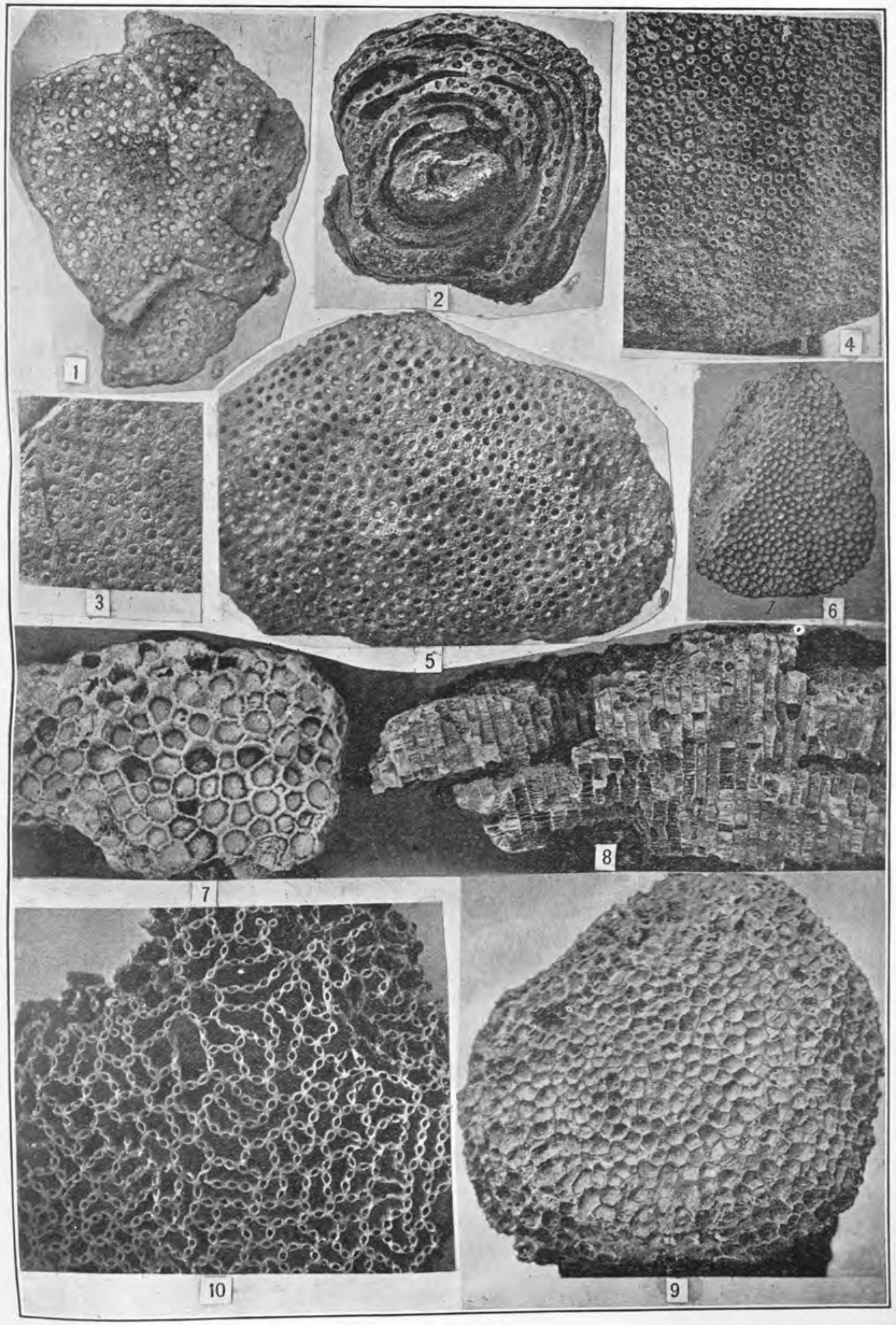

Plate 30.
Corals of the Louisville limestone.

Brachiopods of the Formations of Niagara Age:

Plate 31.

All the Illustrations on this Plate After Nettelroth, Kentucky Fossil Shells.

1 and 2 Atrypa reticularis niagarense. Nettelroth. 1, pedicle; 2, brachial valve. Distinguished from the Devonian form of A. reticularis by its smaller size.

3-4 Rhynchotreta cuneata americana. Hall. 3, brachial; 4, pedicle valve. Louisville limestone and Osgood formation.

5-7 Camarotœchia (?) indianensis. Hall. 5, pedicle; 6, brachial, and 7, side view. Louisville limestone.

8-10 Camarotœchia (?) acinus. Hall. 8, brachial; 9, pedicle, and 10, side view. Louisville limestone.

11-12 Anastrophia internascens. Hall. 11, brachial; 12, pedicle view. Louisville limestone.

13-18 Wilsonia saffordi. (Hall.) Side, brachial, and pedicle views of two different forms. Louisville limestone.

19-20 Uncinulus stricklandi. Sowerby. 19, brachial, and 20, side view. Louisville limestone.

21-22 Gypidula nucleus. Hall and Whitfield. 21, brachial; and 22, front view. Louisville limestone.

23-24 Cyrtia exporrecta. Wahlenberg. 23, cardinal; 24, pedicle, and 25, brachial view. Louisville limestone.

26-28 Dalmanella elegantula. Dalman. 26, profile; 27, pedicle, and 28, brachial view. Brassfield limestone. Osgood formation. Louisville limestone.

29-30 Rhynchospira (?) helena. Nettelroth. 29, brachial; 30, pedicle view. Louisville limestone.

31-32 Meristina maria. Hall. 31, brachial; 32, pedicle view. Louisville limestone.

33-34 Whitfieldella nitida. (Hall.) 33, profile; and 34, brachial view. Louisville limestone.

35-37 Spirifer crispus. Hall. 35, pedicle; 36, brachial; and 37, profile view. Osgood formation, Louisville limestone.

38-40 Rhipidomella hybrida. Sowerby. 38, brachial; 39, pedicle; 40, profile view. Osgood formation, Louisville limestone.

41-42 Gypidula knotti. Nettelroth. 41, pedicle, and 42, brachial view. Louisville limestone.

43 Diaphorostoma niagarense. Hall. Top view of a young or small specimen. Osgood formation, Louisville limestone.

44-45 Conchidium nysius. (Hall and Whitfield.) 44, pedicle; and 45, brachial view. Fairly common in the Louisville limestone.

46-49 Camarotœchia pisa. (Hall and Whitfield.) 46, brachial; 47, front; 48, profile; and 49, pedicle view. Louisville limestone.

50-51 Spirifer (Eospirifer) foggi. Hall. 50, brachial; 51, pedicle view. Louisville limestone.

52-53 Sipirifer (Eospirifer) rostellum. Hall and Whitfield. Brachial and pedicle views. Louisville limestone.

54-55 Spirifer (Eospirifer) radiatus. Sowerby. Brachial and pedicle views.

56-57 Atrypa calvini. Nettelroth. 56, pedicle; 57 brachial view.

58 Orthis nettelrothi. Foerste. Brachial view. Louisville limestone. Closely resembles O. flabellites of the Brassfield and Osgood.

59-60 Pentamerus cylindrica. Hall and Whitfield. 59, pedicle; and 60, brachial view. Fairly common in the Louisville limestone and characteristic of it.

61-62 Orthis (?) rugiplicata. Hall and Whitfield. Pedicle and brachial views. Louisville limestone. Rare.

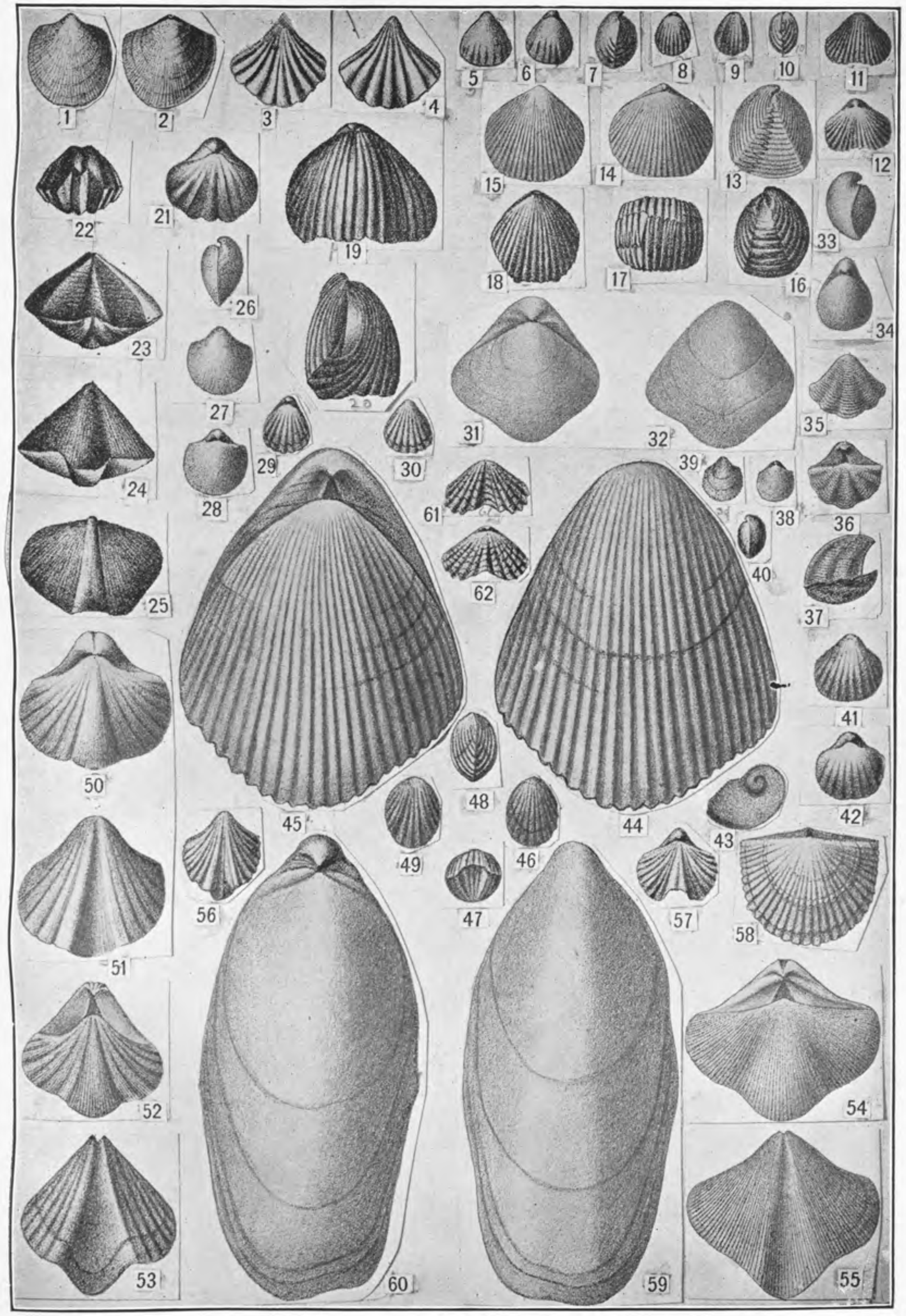

Plate 31.
Brachiopods from rocks of Niagara age.

AGE AND CORRELATION.—Like the Waldron shale, the Louisville limestone is recognizable from Rush County, Indiana, via Jefferson County, Kentucky, to Southern Tennessee. The list of fossils from the latter locality corresponds very closely with that from this county. The Louisville thins northward and in Rush County, Indiana, is only about 8 feet thick. North of Rush County the identification of the Louisville is uncertain. Foerste,* however, regards the Louisville as represented by a part of the limestone of Northern Indiana, which he states carries a good many fossils present in the typical Louisville. Foerste expresses the opinion that the limestone which he correlates with the Louisville lies at a slightly lower horizon than limestone at Huntington, Indiana, in which Kindle† reports several species of the Guelph fauna. If such a relation of the Louisville and Guelph exists the equivalence of the Louisville and part of the upper half of the Lockport dolomite of New York is indicated, for wedges of the Guelph dolomite carrying its peculiar fauna are included in the upper half of the Lockport dolomite. Moreover, the Louisville fauna partakes largely of Rochester (normal) forms, and many of these forms pass up into the Lockport, where they occur in portions of the Lockport intercalated between the wedges carrying the Guelph fauna. Furthermore, inasmuch as neither the Lockport nor Louisville contains any considerable representation of a Cayugan fauna, but almost exclusively a Niagara one, there seems no reason for assigning the Louisville a younger age than upper Lockport, while if in Indiana it underlies limestone carrying a Guelph fauna, as thought by Foerste, there is a convincing reason for its correlation with the uper part of the Lockport. It would follow that the Laurel, Waldron, and Louisville are about equivalent to the whole of the Lockport.

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*Foerste, A. F., Ind. Dept. Geol. & Nat. Res., 28th Ann. Rept., pp. 34 and 35, 1904.

†Kindle, E. M., The Stratigraphy and Paleontology of the Niagara of Northern Indiana: Ind. Dept. Geol. & Nat. Res., 28th Ann. Rept., p. 408, 1904.

UNCONFORMITY BETWEEN THE LOUISVILLE AND JEFFERSONVILLE LIMESTONES.

The Louisville limestone is immediately overlain by limestone of early Middle Devonian age. Between the horizon of the top of the Louisville and that of the bottom of the Middle Devonian limestone which immediately overlies it, there are in Southern Pennsylvania several formations as follows: McKenzie formation 150 feet, Wills Creek shale 750 feet, Tonoloway limestone 500 feet, Helderberg limestone 400 feet, and Oriskany sandstone 400 feet, aggregating 2,200 feet of strata. In other words, during the long period necessary for the accumulation of the post-Louisville strata enumerated, no sediment was deposited in Jefferson County or in the central western region generally, or if any was deposited, either of general or local extent, it was removed before the deposition of the Devonian limestones began. The simplest explanation is that, at the close of Louisville time, the sea floor was elevated above sea level and the region was a land surface until Middle Devonian time when resubmergence took place and deposition was resumed. Such a course of events would result in the existing condition. Notwithstanding the long interval involved in this unconformity, the contact between the Louisville and the Devonian limestone is remarkably even and close. In fact, where best exposed, as in quarries, the contact is in the midst of a solid layer about 8 feet thick without visible partings in the fresh faces, so that the presence of the contact can be detected only by close examination. In reality, however, the faunal and lithic change is absolutely sharp and definite and easily recognized when the distinctive characters have been learned by experience. Silurian fossils are fairly abundant up to the dividing line, but are not present above it. *Halysites catenularia* for example is especially abundant to the very top of the Louisville, where it can be found almost if not quite in contact with the abundant and varied Devonian corals in the bottom of the Devonian limestone. The latter limestone, too, is very much coarser grained and darker than the Louisville.

The contact is revealed by weathering which affects the two limestones differently. Weathering brings the chert layers of the Louisville into relief, and as chert is

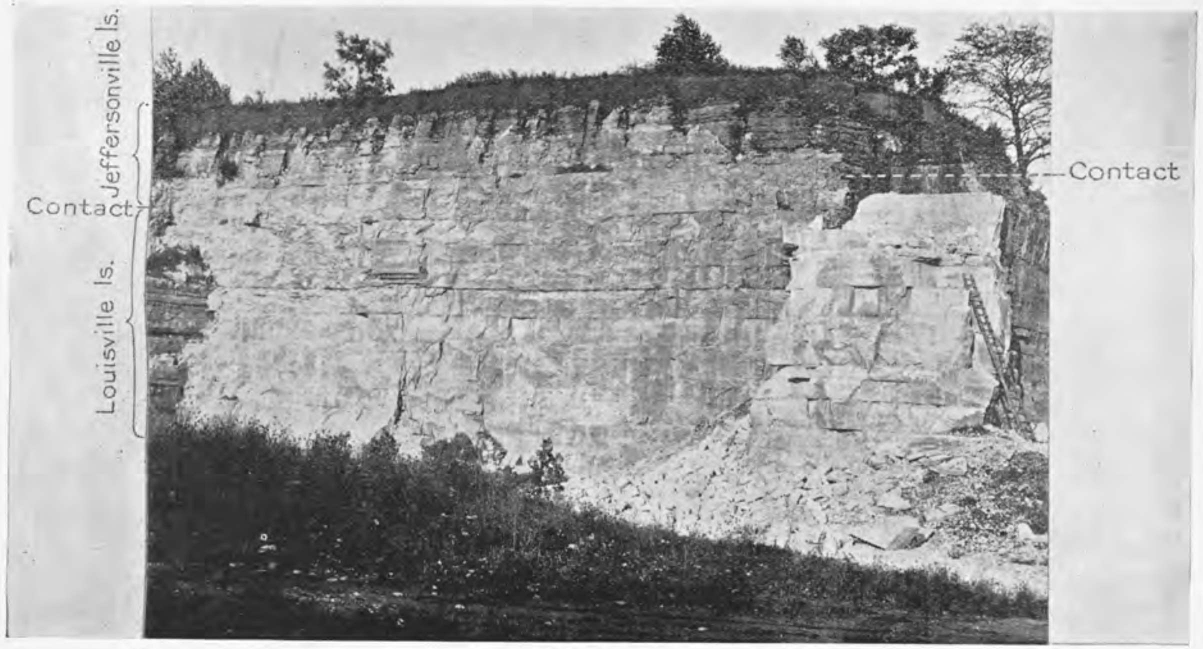

Plate 32.

View in quarry on Beargrass Creek in the eastern part of Louisville, showing the Louisville and Jeffersonville limestones, with the line of contact near the middle of a massive layer near top of quarry. The notch near the middle of the layer containing the contact is where the hammer head rests in Plate 33. Looking east.

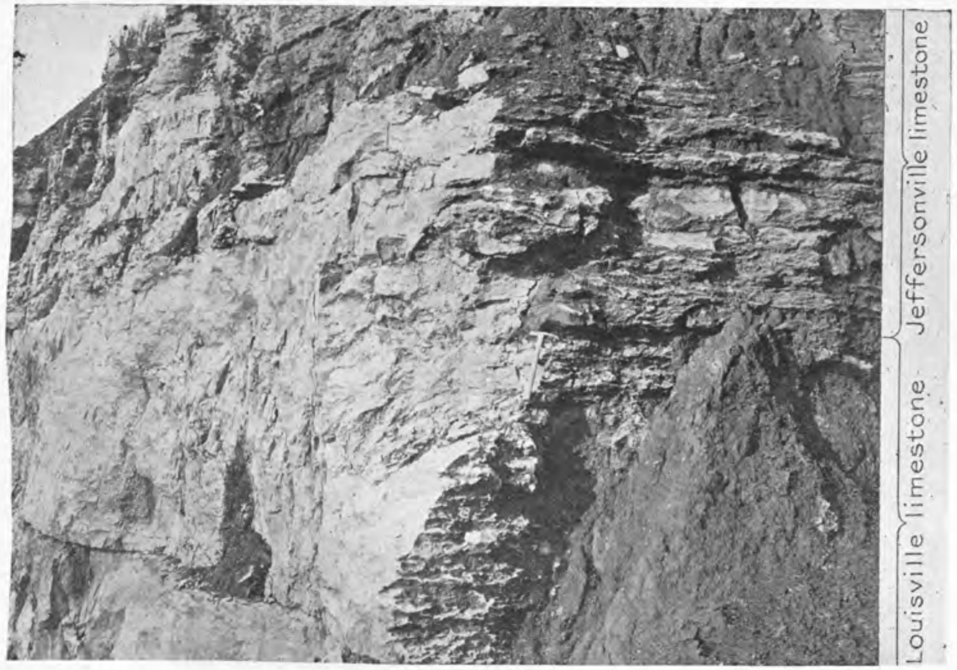

Plate 33.

Nearer view of the right hand end of Plate 32. Hammer head at contact of Louisville and Jeffersonville limestones. The contact is above the middle of a massive layer 8 feet thick with conspicuous bedding planes above and below. Halysites in top of layers on which hammer rests and large horn or cup corals of Devonian age in the layer touched by top of hammer head. Looking north.

apparently wanting in the Devonian and quite plentiful in the Louisville immediately below the Devonian, the contact of the two limestones can be located from a distance on well weathered surfaces. These features are clearly shown on Plates 32 and 33.

The most significant feature illustrated by these photographs is perhaps the perfect parallelism of the bedding in the two unconformable formations and the evenness of the contact between them. These characteristics imply uniformity of upward and downward movement of the region in the time represented by the unconformity, resulting in the absence of any strong deformation of the previously formed strata so that any departure from their original horizontality is so slight that it is not perceptible in the length of any existing exposure. Furthermore, if the land surface was raised much above sea level it must have been worn down close to sea level before it was again submerged, else the land must have been furrowed by valleys and the Devonian laid down upon an irregular surface like that between the Saluda and Brassfield in places as illustrated in Plate 21.

Another feature of this unconformity requires stating. Both the Jeffersonville limestone and the Silver Creek member of the Sellersburg limestone wedge out southward so that in the southern part of the county, as shown on Mud Creek east of the angle in the ridge between South Park and Norton Hills, and in the creek between Brooks and Button Mould Knob 1 mile or so south of the county, the Beechwood ("Encrinal") member of the Sellersburg rests upon the Louisville limestone. The Beechwood member thus overlaps the underlying Devonian limestones southward, a relation resulting from the southeastward transgression of the sea on a sinking coastal margin.

DEVONIAN SYSTEM.

The Devonian system in Jefferson County comprises three formations named in ascending order as follows: Jeffersonville limestone, Sellersburg limestone, and the New Albany (black) shale, in part at least, if not the whole. The age of the New Albany, however, is a controverted question which is discussed in the description of that formation. The Sellersburg limestone is divided into two members, viz.: The Silver Creek (hydraulic) limestone (cement bed), below and the Beechwood limestone ("Encrinal bed," Sellersburg limestone of Siebenthal) above.

JEFFERSONVILLE LIMESTONE.

NAME AND DEFINITION.—The name Jeffersonville was introduced by Kindle* from the City of Jeffersonville in the vicinity of which the limestone is extensively exposed in the banks and the bottom of Ohio River. It includes the limestone between the unconformity at the top of the Louisville limestone described above, and the distinctly differentiated and well known hydraulic limestone or cement bed of the region.

DISTRIBUTION.—The surface distribution of the Jeffersonville limestone is confined to the northern-central part of the county. It outcrops in the bed of Ohio River on the Kentucky side and in the bed and on the banks on the Indiana side northwest of Jeffersonville to within a half a mile of the mouth of Silver Creek where it dips below water level. On the Kentucky side beneath the J. M. & I. bridge it is covered by about 1 foot of the Silver Creek limestone member for some distance out into the river. Its contact with the Silver Creek shows about 100 yards below the Louisville end of the bridge. The formation caps extensive upland areas in the county within limits roughly indicated by a line drawn from Louisville through Whitner and thence northeastward through Middletown to the county boundary. It is not certainly known to be present in undecomposed condition over all the patches mapped in this area, but it was observed in place

*Kindle, E. M., American Paleontology, Bull. No. 12, 1899.

at some points, its clay, a peculiar red, or chert bearing its fossils, particularly *Spirifer gregarius,* were observed at many points even as far southeast as Anchorage. It is believed that such evidence is sufficient to warrant the conclusion of the presence of the limestone, even though only a thin residual body, in most of the patches. Where other evidence is wanting the limestone is mapped on topographic evidence or, in other words, where the upland areas are high enough to carry it. Such an area is the one just northwest of Middletown. The Jeffersonville is known by its residual red clay to extend as far southeast as the brick works 1 mile east of Whitner, but was not certainly observed farther southeast. As already stated it is absent to the east of Norton Hills in the southern part of the county. Somewhere between Whitner and the last point mentioned, therefore, the Jeffersonville wedges out presumably by loss of layers from the bottom. Since the New Albany shale and the Louisville limestone are very close together south of Petersburg it is assumed that only the Beechwood member of the Sellersburg limestone is present between them, and that the Jeffersonville limestone disappears somewhere between Petersburg and the brick plant mentioned above.

THICKNESS.—No complete section exposing both top and bottom of the Jeffersonville limestone was discovered in the region so that no precise measurement could be made. However, the thickness, probably to within a foot or two, was determined on the Indiana side of Ohio River at the Whirlpool 1 mile west of Jeffersonville and on the bluff and at the quarries northeast of Louisville. A section compiled from exposures near the Whirlpool is 23 feet 4 inches thick. Possibly a foot or two should be added to the top of this, and at least 3 feet of limestone outcrops below water that could not be seen or identified. It is probably safe, however, to consider the thickness as at least 25 feet on the Indiana side of the river. A section measured on the bluff at the Country Club 2 miles northeast of Louisville is 18 feet thick. Here the top is not certainly exposed, but the highest bed has *Spirifer acuminatus*, and as that form is limited to a layer about 4 feet thick at the top of the Jeffersonville, the whole thickness probably is not more than 2 feet greater, or 20 feet. Sixteen feet of Jeffersonville is exposed in Shanks'

quarry at Louisville, the upper few feet having disintegrated into soil. As previously stated, the Jeffersonville thins to nothing southward. No measurements were obtainable in the northern part of the county, but a thickness of 20 feet is assumed in mapping.

CHARACTER.—The general character of the Jeffersonville is illustrated by the following section:

Section of Jeffersonville Limestone at the Whirlpool 1 Mile West of Jeffersonville, Indiana. Partly Compiled.

		Feet.
5.	Limestone, massive, rather coarse-grained, light-gray, a little black chert locally. Whitish and shelly on weathering. Exfoliates diagonally to the bedding. Spirifer acuminatus about in top. Stropheodonta hemispherica, abundant and conspicuous, Bryozoa abundant, includes bryozoan and Nucleocrinus subzones of authors. Sp. acuminatus zone. (See Plate 34.)	9*
4.	Limestone, siliceous, cherty, bluish-gray, fine-grained, very hard. Spirifer gregarius, very abundant. Favosites hemisphericus, Turbo shumardi, &c. Spirifera gregarius zone	2
3.	Limestone, 6 inches to 1 foot layers, medium, coarse grained, light pinkish, bluish, or brownish gray. In places largely made up of Stromatopora	7
2.	Limestone, medium thick-bedded, very coarse crystalline, brownish in part. Crowded with corals. (See Plate 38.) Coral layer	7*
	Certainly Jeffersonville	25
1.	Limestone, covered with water, not identified	3

The following series of photographs, Plates 34, 35, 36 and 37, illustrate some of the features of the Jeffersonville limestone as described in the above section:

The sequence of lithic and faunal characters shown in the above section seems to hold throughout the county wherever the Jeffersonville has anything like its normal thickness. The basal coral zone is persistent and wherever it is exposed immediately overlying the top of the Louisville, in which *Halysites catenularia* can generally be found, the layers are seen to be crowded with the various kinds of corals, some of which are shown in Plate 38. This basal, coarse-grained limestone is of a dark-brownish color and films of black, carbonaceous matter penetrate the rock along its corrugated lamination planes.

*More or less.

Plate 34.

Jeffersonville limestone, Spirifer acuminatus zone on the top of which the man stands, the Silver Creek (hydraulic) member of the Sellersburg limestone (cement bed) behind man, and detached remnants of limestone lying on the Silver Creek member. Diagonal exfoliation of the Jeffersonville well shown. Indiana shore of Ohio River about ¾ mile east of Sand Island. Looking east.

Plate 35.

Middle and lower part of the Jeffersonville limestone. Man sits on the top of the lower especially coraliferous layers. The heavy layers above are largely made up of Stromatopora. Indiana shore of Ohio River 1 mile northwest of J. M. & I. (middle) bridge. Looking west.

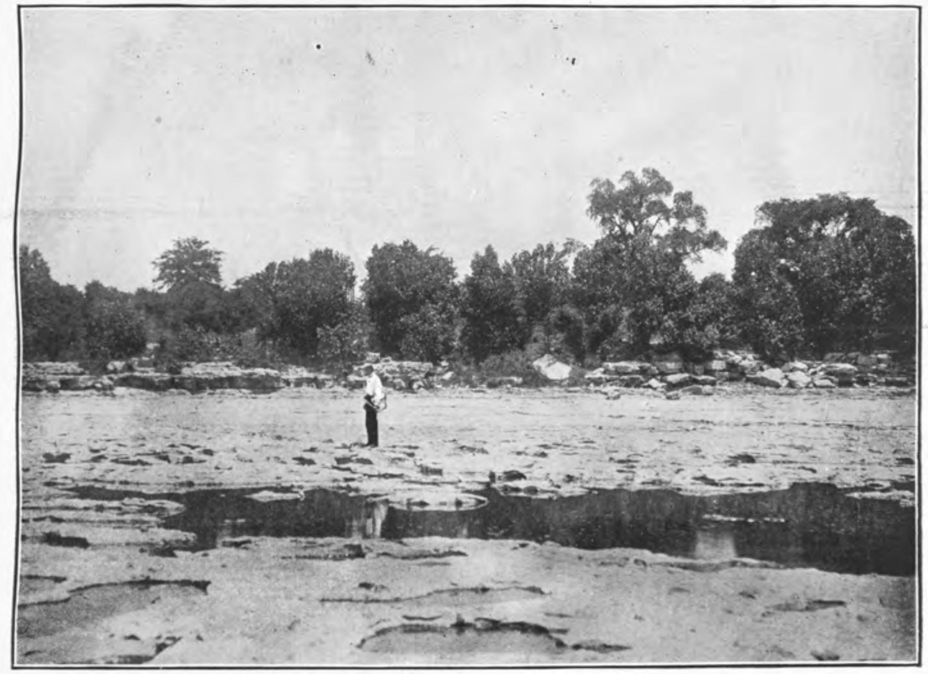

Plate 36.

Basal coraliferous layers of the Jeffersonville limestone in the bed of Ohio River. This bare expanse of limestone extends for several hundred yards west of the J. M. & I. (middle) bridge, and its surface is covered with a mat of fossil corals. Looking north.

Plate 37.

Block of the Spirifer gregarius layer covered with the projecting silicified shells of that fossil. Indiana shore several hundred feet west of J. M. & I. bridge.

Plate 38.

View of limestone surface shown in Plate 36, illustrating the mat of corals which covers its whole surface about as shown in this photograph. These forms seem to be about as abundant as shown all through the lower 6 to 10 feet of the Jeffersonville limestone making it a veritable coral reef. The small forms are Cladopora and Striolopora, the others are various species of cup corals. Scale 1 inch = 5¼ inches of nature.

The carbon is presumably a carbonized residue of the organic matter of the corals. A sample of this limestone from Shanks' quarry contained nearly 95 per cent. calcium carbonate and about 3 per cent. silica (see analysis No. G.3612). Likewise the *Spirifer gregarius* zone persists throughout and its chert and silicified shells of *Spirifer gregarius* are generally to be found wherever there is any evidence of the presence of the formation; in some cases, indeed, they are, themselves, the only evidence of its presence. Wherever also the top layers of the Jeffersonville have been observed either *Spirifer acuminatus* or *Stropheodonta hemispherica* is generally present.

FOSSILS.—The abundance and perfection of the fossils of the Jeffersonville limestone, especially of the fossil corals, have contributed largely to the fame of the "Falls of the Ohio," among paleontologists the world over. The fossils have been described by several authors, the more prominent of whom are Hall, Davis, Nettelroth, Ulrich, Rominger, and Kindle.

A list of the described fossils quoted from these authors follows. The list of corals is from Davis, that of brachiopods, pelecypods and gastropods is from Nettelroth, that of the Bryozoa is from Hall and Ulrich, and that of the ostracods is from Ulrich, and of the trilobites is from Kindle. In the matter of names of the brachipods, Schuchert* and Bassler† are followed where they differ from Nettelroth.

There are probably errors both of omission and inclusion in this list. So far, however, as the records show any doubt as to the occurrence of a species in the Jeffersonville limestone its name has been omitted from the list. It seems probable that most of the forms of the Jeffersonville as well as the Sellersburg limestone are known, since collectors have been at work upon them for many years, and therefore the lists should include very nearly if not all the forms actually present in these limestones.

*Schuchert, Charles. A synopsis of American Fossil Brachiopoda: U. S. Geol. Survey Bull. 87, 1897.

†Bassler, R. S., The Nettelroth collection of invertebrate fossils: Smithsonian Misc. Coll., vol. 2, pt. 2, 1908.

List of Fossils from the Jeffersonville Limestone.

The species occurring also in the Columbus limestone of Ohio and in the Onondaga limestone of New York are denoted by the abbreviations of the names of those states following the name of the species.

Corals.

Acrophyllum clarki. Davis.
Acrophyllum ellipticum. Davis.
Acrophyllum oneidaense. Billings.
Alveolites constans. Davis.
Alveolites minimus. Davis.
Alveolites mordax. Davis.
Alveolites squamosus. Billings.
Aulacophyllum conigerum. Davis.
Aulacophyllum insigne.
Aulacophyllum mutabile. Davis.
Aulacophyllum parvum. Davis.
Aulacophyllum sulcatum. D'Orbigny.
Aulacophyllum unguloideum. Davis.
Aulopora cornuta. Billings.
Aulopora culmula. Davis.
Aulopora edithana.
Aulopora procumbens. Davis.
Aulopora serpens. Goldfuss.
Blothrophyllum approximatum. Nicholson.
Blothrophyllum cinctutum. Davis. O.
Blothrophyllum corium. Davis.
Blothrophyllum decorticatum. Billings.
Blothrophyllum liratum. Davis.
Blothrophyllum louisvillense. Davis.
Blothrophyllum parvulum. Davis.
Blothrophyllum sessile. Davis.
Blothrophyllum zaphrentiforme. Davis.
Chonophyllum magnificum. Billings. O.
Chonophyllum multiplicatum. Davis.
Cladopora acupicta. Davis.
Cladopora alpenensis. Rominger.
Cladopora aspera. Rominger.
Cladopora billingsi?
Cladopora bifurca. Davis.
Cladopora crassa. Davis.
Cladopora cryptodens. Billings. N. Y.
Cladopora dentata. Davis.
Cladopora desquamata. Davis.
Cladopora dispansa. Davis.
Cladopora expatiata. Rominger.
Cladopora fibrata. Davis.

Cladopora francisci. Davis.
Cladopora gracilis. Davis.
Cladopora imbricata. Rominger.
Cladopora iowaensis. Owen.
Cladopora labiosa. Billings. N. Y.
Cladopora pinguis. Rominger.
Cladopora pulchra. Rominger. O.
Cladopora radula. Davis.
Cladopora ricta. Davis.
Cladopora rimosa. Rominger.
Cladopora robusta. Rominger. O.
Cladopora roemeri?
Cladopora tela. Davis.
Cyathophyllum brevicorne. Davis.
Cyathophyllum coralliferum?
Cyathophyllum corniculum. Lesueur. N. Y.
Cyathophyllum davidsoni. Edwards and Haime.=Acervularia dandsoni.
Cyathophyllum detextum. Davis.
Cyathophyllum fimbriatum. Davis.
Cyathophyllum flos. Davis.
Cyathophyllum greeni. Davis.
Cyathophyllum ligatum. Davis.
Cyathophyllum multigemmatum. Davis. O.
Cyathophyllum oedipus. Davis.
Cyathophyllum ovoideum. Davis.
Cyathophyllum pocillum. Davis.
Cyathophyllum pumilus. Davis.
Cyathophyllum robustum. Hall. N. Y.
Cyathophyllum rugosum. Hall. O.
Cyathophyllum winchelli. Davis.
Cystiphyllum cicatriciferum. Davis.
Cystiphyllum cuyagaense?
Cystiphyllum edwinanum. Davis.
Cystiphyllum grande. Billings.
Cystiphyllum hispidum. Davis.
Cystiphyllum limbatum. Davis.
Cystiphyllum lienatum. Davis.
Cystiphyllum nettelrothi. Davis.
Cystiphyllum os. Davis.
Cystiphyllum plicatum. Davis.
Cystiphyllum squamosum. Nicholson.
Cystiphyllum sulcatum. Hall. O., N. Y.
Cystiphyllum theissi. Davis.
Cystiphyllum tumidosum. Davis.
Cystiphyllum vesiculosum. Goldfuss. O.
Dendropora elegantula. Billings.

Dendropora proboscidalis. Rominger.
Diphyphyllum bellis. Davis. O.
Diphyphyllum coagulatum. Davis.
Diphyphyllum coalescens. Davis.
Diphyphyllum conjunctum. Davis.
Diphyphyllum gigas. Rominger.
Diphyphyllum panicum. Davis.
Diphyphyllum strictum. Edwards and Haime. O.
Diphyphyllum verneuilanum. Edwards and Haime. O.
Drymopora (Syringopora) commensalis. Davis.
Drymopora (Syringopora) fascicularis.
Drymopora (Syringopora) intermedia. Nicholson.
Drymopora (Syringopora) nobilis. Billings.
Eridophyllum arundinaceum. Billings.
Eridophyllum simcoense. Billings. N. Y.
Favosites amplissimus. Davis.
Favosites arbor. Davis.
Favosites baculus. Davis.
Favosites canadensis. Billings. N. Y.
Favosites cariosus. Davis.
Favosites clausus. Rominger.
Favosites clelandi. Davis.
Favosites convexus. Davis.
Favosites cymosus. Davis.
Favosites digitatus. Rominger.
Favosites emmonsi. Rominger. O., N. Y.
Favosites epidermatus. Rominger.
Favosites frutex. Davis.
Favosites fustiformis. Davis.
Favosites hemisphericus and varieties. Troost. O., N. Y.
Favosites impeditus. Davis.
Favosites intertextus. Rominger.
Favosites limitaris. Rominger. O.
Favosites mundus. Davis.
Favosites ocellatus. Davis.
Favosites pirum. Davis.
Favosites proximus. Davis.
Favosites quercus. Davis.
Favosites radiatus. Rominger.
Favosites radiciformis. Rominger.
Favosites ramulosus. Davis.
Favosites spiculatus. Davis.
Favosites tuberosus. N. Y.
Hadrophyllum d'Orbignyi. Edwards and Haime. O.
Heliophyllum (Cyathophyllum) colligatum. Billings.
Heliophyllum (Cyathophyllum) exignum. Billings. N. Y., O.

Heliophyllum (Cyathophyllum) halli. Edwards and Haime.
Heliophyllum (Cyathophyllum) infoveatum. Davis.
Heliophyllum (Cyathophyllum) multicrena. Davis.
Michelinia clappi. (?)
Michelinia corrugata. Davis.
Michelinia cylindrica. (?) N. Y.
Platyaxum (Cladopora, Pachypora) canadense. Rominger.
Platyaxum corioideum. Davis.
Platyaxum fischeri. Billings.
Platyaxum foliatum. Davis.
Platyaxum turgidum. Billings.
Platyaxum undosum. Davis.
Procteria michelinoidea. Davis.
Procteria papillosa. Davis.
Ptychophyllum coniferum. Davis.
Ptychophyllum diaphragma. Davis.
Ptychophyllum tropeum. Davis.
Ptychophyllum typicum. Davis.
Romingeria incrustans. Davis.
Romingeria umbellifera. Billings.
Romingeria uva. Davis.
Striatopora alba. Davis.
Striatopora linnæana. Billings.
Syringopora bouchardi. Nicholson.
Syringopora hisingeri. Billings.
Syringopora perelegans. Billings. O., N. Y.
Syringopora straminea. Davis.
Syringopora tabulata. Edwards and Haime.
Syringopora tubiporoides. Yandell and Shumard.
Thecia ramosa. Rominger.
Zaphrentis compressa. Edwards.
Zaphrentis (Cleisophyllum) conigera. Billings.
Zaphrentis exilis. Davis.
Zaphrentis gigantea. Lesueur. O., N. Y.
Zaphrentis greenana. Davis.
Zaphrentis immanis. Davis.
Zaphrentis linneyi. Davis.
Zaphrentis maconathi. Davis.
Zaphrentis nodulosa. Rominger.
Zaphrentis prolifica. Billings.
Zaphrentis rafinesque. Edwards and Haime.
Zaphrentis romingeri. Davis.
Zaphrentis torquata. Davis.
Zaphrentis trigemma. Davis.
Zaphrentis yandelli. (?)

Crinoids.

Ancyrocrinus spinosus. Hall. N. Y.
Codaster americanus. Shumard.
Codaster pyramidatus. Shumard. O., N. Y.
Dolatocrinus lacus. Lyon. O.
Dolatocrinus marshi. Lyon.
Megistocrinus knappi. Lyon and Casseday.
Megistocrinus spinulosus. Lyon. O., N. Y.
Nucleocrinus angularis. Lyon.
Nucleocrinus greeni. Miller and Gurley.
Nucleocrinus venustus. Miller and Gurley. O.
Nucleocrinus verneuili. Troost. O.
Poteriocrinus cylindricus. Lyon. N. Y.
Poteriocrinus simplex. Lyon. N. Y.

Bryozoa.

Botryllopora socialis. Nicholson.
Buskopora bistriata. Hall.
Buskopora dentata. Ulrich.
Buskopora pyriformis. Hall.
Chaetetes? ponderosus. Hall.
Chaetetes? tenuis. Hall.
Clonopora semireducta. Hall.
Coscinium cribriforme. Prout.
Cystopora geniculata. Hall.
Cystodictya gilberti. Meek. O.
Cystodictya ovatipora. Hall. O.
Cystodictya vermicula. Hall.
Dekayia devonica. Ulrich.
Discotrypa? devonica. Ulrich.
Eridopora? clivulata. Hall.
Eridopora denticulata. Hall.
Fenestella aequalis. Hall.
Fenestella cultrata. Hall.
Fenestella curvijunctura. Hall.
Fenestella depressa. Hall.
Fenestella perplexa. Hall.
Fenestella proutana. Miller.
Fenestella pulchella. Ulrich.
Fenestella serrata. Hall.
Fenestella singularitas. Hall.
Fenestella stellata. Hall.
Fenestella tenella. Hall.
Fenestella variapora. Hall.
Fenestella verrucosa. Hall.
Fenestrapora infraporosa. Ulrich.
Fistulipora alternata. Hall.

Fistulipora conulata. Hall.
Fistulipora geometrica. Hall.
Fistulipora granifera. Hall.
Fistulipora normalis. Ulrich.
Fistulipora ovata. Hall.
Fistulipora subcava. Hall.
Fistulipora substellata. Hall. O.
Glossotrypa paliformis. Hall.
Hederella adnata. Davis.
Hederella canadensis. Nicholson. O.
Hederella cirrhosa. Hall.
Helicopora ulrichi. Claypole.
Hemitrypa cribrosa. Hall.
Hernodia humifusa. Hall.
Intrapora puteolata. Hall.
Lichenotrypa longispina. Hall.
Lioclema intercellatum. Hall.
Orthopora regularis. Hall. O.
Orthopora rhombifera. Hall.
Phractopora cristata. Hall.
Phyllopora aspera. Ulrich.
Polypora aculeata. Hall.
Polypora blandida. Ulrich.
Polypora celsipora minor. Hall. O.
Polypora intermedia. Prout.
Polypora laevistriata. Hall.
Polypora levinodata. Hall.
Polypora quadrangularis. Hall.
Polypora shumardi. Prout.
Polpora striatopora. Hall.
Polypora submutans. Hall.
Polypora transversa. Ulrich.
Prismopora sparsipora. Hall.
Prismopora triquetra. Hall. O.
Ptiloporella? bifurca. Ulrich.
Reteporidra adnata. Hall.
Rhombopora lineinoides. Ulrich.
Rhombopora lineinoides-humilis. Ulrich.
Scalaripora scalariformis. Hall.
Scalaripora subconcava. Hall.
Selenopora circincta. Hall.
Selenopora complexa. Hall.
Semicoscinium biimbricatum. Hall. O.
Semicoscinium biserrulatum. Hall.
Semicoscinium interruptum. Hall.
Semicoscinium latijuncturum. Hall.
Semicoscinium lunulatum. Hall.

Semicoscinium permarginatum. Hall.
Semicoscinium planodorsatum. Ulrich.
Semicoscinium rhomboideum. Prout.
Semicoscinium semirotundum. Hall.
Semicoscinium tortum. Hall.
Semicoscinium tuberculatum. Prout.
Strotopora perminuta. Ulrich.
Thamniscus nanus. Hall.
Trematella annulata. Hall.
Trematella arborea. Hall. O.
Unitrypa acaulis. Hall.
Unitrypa anonyma. Hall.
Unitrypa fastigata. Hall.
Unitrypa tegulata. Hall. O.

Brachiopoda.
Athyris fultonensis. Swallow.=A. vittata. O.
Atrypa ellipsoida. Nettelroth.
Atrypa reticularis. Linnaeus. O., N. Y.
Camarotoechia carolina. Hall. O.
Camarotoechia tethys. Billings. O., N. Y.
Chonetes mucronatus. Hall. O.
Cranaena (Terebratula) romingeri. Hall.
Cyrtina crassa. Hall. O., N. Y.
Eunella (Terebratula) harmonia. Hall. O.
Eunella (Terebratula) lincklaeni. Hall.
Meristella nasuta. Conrad. O., N. Y.
Nucleospira concina. Hall.
Parazyga (Trematospira) hirsuta. Hall.
Pentamerella arata. Conrad. O., N. Y.
Pentamerella pavilionensis. Hall. O.
Pentamerella thusnelda. Nettelroth.
Pholidostrophia iowaensis. Owen.=Strophodonta nacrea. O.
Productella semiglobosa. Nettelroth.
Rhynchonella louisvillensis. Nettelroth.
Rhynchonella tenuistriata. Nettelroth.
Schuchertella (Streptorhynchus) chemungensis arctistriata. Hall.'
Spirifer acuminatus. Conrad. O., N. Y.
Spirifer arctisegmentum. Hall. N. Y.
Spirifer audaculus. Conrad.
Spirifer davisi. Nettelroth.
Spirifer divaricatus. Hall. O., N. Y.
Spirifer duodenarius. Hall. O., N. Y.
Spirifer fornacula. Hall. O.
Spirifer gregarius. Hall. O., N. Y.
Spirifer greiri. Hall. O., N. Y.
Spirifer raricosta. Hall. O., N. Y.

Spirifer segmentum. Hall. O.
Spirifer varicosus. Hall. O., N. Y.
Stropheodonta demissa. Conrad. O., N. Y.
Stropheodonta hemispherica. Hall. O., N. Y.
Stropheodonta inequistriata. Conrad. O., N. Y.
Stropheodonta perplana. Conrad. O., N. Y.
Stropheodonta plicata. Hall.
Terebratula jucunda. Hall.

Pelecypods.
Actinopteria boydi. Conrad. O.
Aviculopecten fasciculatus. Hall. O.
Aviculopecten pecteniformis. Conrad. O., N. Y.
Aviculopecten princeps. Conrad. O.
Conocardium cuneus. Conrad. O., N. Y.
Cypricardinia cataracta. Conrad.
Glyptodesma cancellata. Nettleroth.
Glyptodesma occidentale. Hall. O.
Goniophora truncata. Hall.
Modiomorpha affinis. Hall.
Modiomorpha mytiloides. Conrad.
Paracyclas elliptica. Hall.

Gastropods.
Bucania devonica. Hall and Whitfield.
Callonema bellatulum. Hall. O.
Callonema clarki. O.
Callonema imitator. Hall and Whitfield. O.
Cyclonema multilirata. Hall.
Murchisonia desiderata. Hall. O.
Platyceras bucculentum. Hall. O.
Platyceras compressum. Nettelroth.
Platyceras conicum. Hall. N. Y.
Platyceras dumosum. Conrad. O., N. Y.
Platyceras dumosum var. rarispinum. Hall. N. Y.
Platyceras erectum. Hall. O., N. Y.
Platyceras milleri. Nettelroth.
Platyceras multispinosum. Meek.
Platyceras rictum. Hall. O., N. Y.
Platyceras symmetricum. Hall. N. Y.
Platyceras thetis. Hall. O., N. Y.
Platyceras ventricosum. Conrad.
Platyostoma turbinatum. Hall.
Pleuronotus (Euomphalus) decewi. Billings. O., N. Y.
Pleurotomaria arabella. Nettelroth.
Pleurotomaria lucina. Hall. O., N. Y.
Pleurotomaria procteri. Nettelroth. O.

Pleurotomaria sulcomarginata. Conrad.
Strophostylus varians. Hall. O., N. Y.
Trochonema rectilalera. Hall. N. Y.
Trochonema yandellana. Hall and Whitfield.
Turbo shumardi. De Verneuil. O., N. Y.

Cephalopods.
Gomphoceras sp.?
Goniatites discoideus. Hall.
Gyroceras inelegans? Meek.

Ostracods.
Leperditia? subrotunda. Ulrich.
Isochilina rectangularis. Ulrich.
Aparchites inornatum. Ulrich.
Beyrichia lyoni. Ulrich.
Beyrichia kolmodini. Jones.
Ctenobolbina spinulosa. Ulrich.
Ctenobolbina armata. Ulrich.
Ctenobolbina cavimarginata. Ulrich.
Ctenobolbina insolens. Ulrich.
Ctenobolbina papillosa. Ulrich.
Ctenobolbina informis. Ulrich.
Ctenobolbina antespinosa. Ulrich.
Kirkbya subquadrata. Ulrich.
Kirkbya parallela. Ulrich.
Kirkbya semimuralis. Ulrich.
Kirkbya cymbula. Ulrich.
Kirkbya germana. Ulrich.
Bollia ungula. Jones.
Bollia obesa. Ulrich.
Halliella retifera. Ulrich.
Octonaria stigmata. Ulrich.
Octonaria stigmata var. loculosa. Ulrich.
Octonaria ovata. Ulrich.
Octonaria clavigera. Ulrich.
Bythocypris devonica. Ulrich.
Bythocypris punctulata. Ulrich.
Bythocypris indianensis. Ulrich.
Pachydomella tumida. Ulrich.
Barychilina punctostriata. Ulrich.
Barychilina punctostriata var. curta. Ulrich.
Barychilina pulchella. Ulrich.

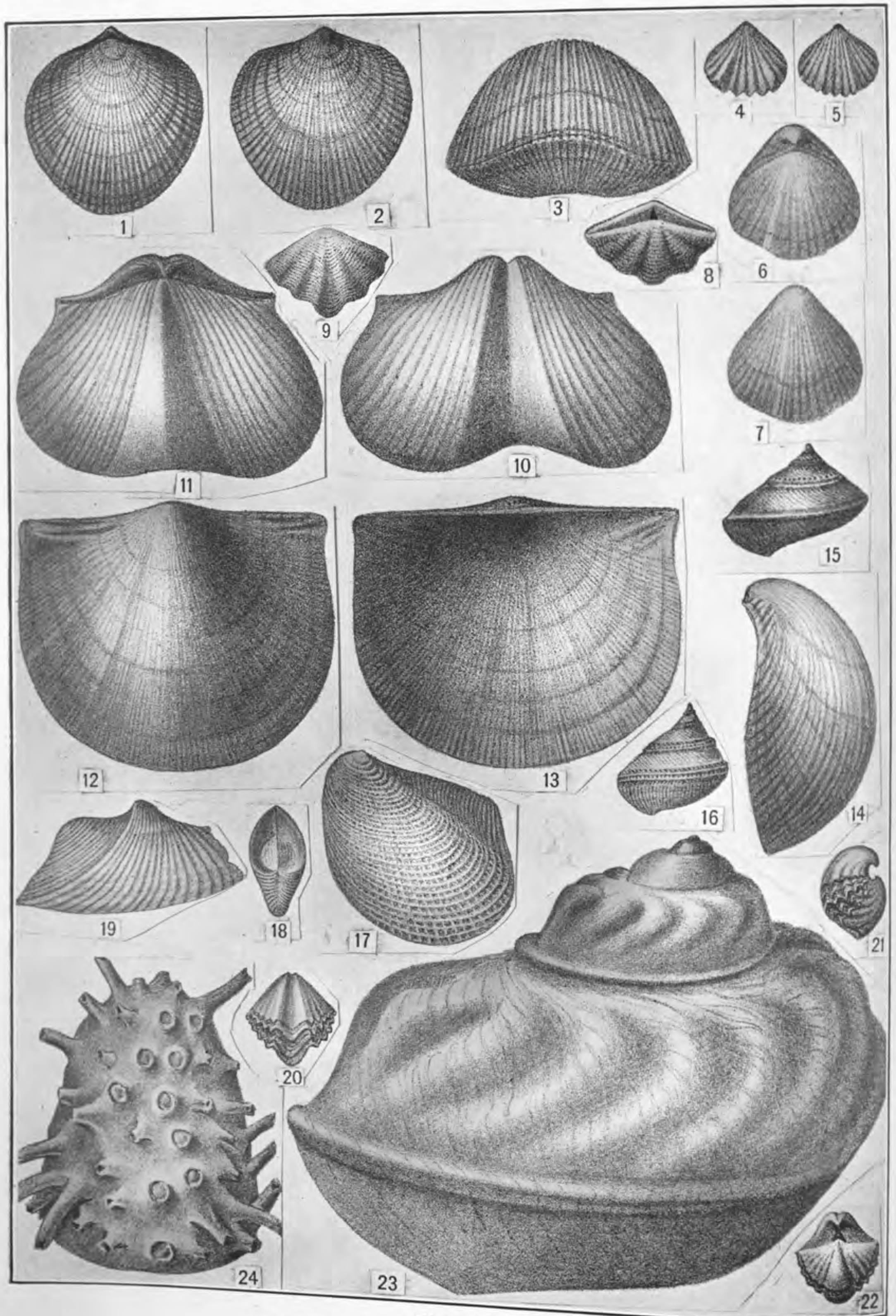

Plate 39.
Fossil Shells of the Jeffersonville Limestone.

Trilobites.

Calymene platys. Green.
Dalamanites (Odontocephalus) aegeria. Hall. O., N. Y.
Dalmanites anchiops. Green. N. Y.
Dalmanites aspectans. Conrad.
Dalmanites helena. Hall. N. Y.
Dalmanites pleuroptyx. Green.
Dalmanites selenurus. Hall and Clarke. N. Y.
Lichas sp.?
Phacops cristata. Hall. O.
Phacops cristata var. pipa. Hall and Clarke. N. Y.
Phacops rana. Green.
Proetus canaliculatus. Hall and Clarke. N. Y.
Proetus clarus. Hall. N. Y.
Proetus crassimarginatus. Hall. O., N. Y.
Proetus microgemma. Hall and Clarke. N. Y.
A few of the species listed above are illustrated in Plates 39 and 40.

Fossil Shells of the Jeffersonville Limestone Most of Them Characteristic. All After Nettelroth, Kentucky Fossil Shells.

Plate 39.

1-3 Atrypa reticularis. Linnaeus. 1, brachial; 2, pedicle; and 3, front view. Common in the Jeffersonville limestone. Occurs also just as commonly in the Sellersburg limestone. Easily distinguished from the Niagara form by its larger size.

4-5 Camarotœchia tethys. Billings. 4, pedicle; and 5, brachial valve. Jeffersonville limestone only. Common.

6-7 Pentamerella pavillionensis. Hall. Brachial and pedicle views. Jeffersonville limestone only.

8-9 Spirifer raricosta. Conrad. Brachial and pedicle views. Jeffersonville limestone only. Rather rare.

10-11 Spirifer acuminatus. Conrad. 10, pedicle; 11, brachial valve. Jeffersonville limestone only. The brachial valve is rarely preserved, the exfoliated pedicle valve with a broad sinus or furrow, is abundant in the top 4 or 5 feet of the Jeffersonville limestone, whence the name Spirifer acuminatus bed. Many specimens of this valve lying with the exterior upwards may be seen in the very top of the Jeffersonville at the river's edge on the Indiana side midway between the mouth of Silver Creek and the whirlpool, and they are common in the top of the Jeffersonville on the Kentucky side of the river a few rods below the end of the Pennsylvania railroad bridge.

12-14 Stropheodonta hemispherica. Hall. 12, pedicle; 13, brachial; and 14, profile view. Jeffersonville limestone associated with Spirifer acuminatus. Common. Conspicuous by its white shell.

15 Pleurotomaria sulcomarginata. Conrad. Jeffersonville limestone only.
16 Pleurotomaria proceteri. Nettelroth. Jeffersonville limestone only.
17 Actinopteria boydi. Conrad. Left valve. Jeffersonville limestone only.
18-19 Conocardium cuneus. Conrad. 18, top view of a young specimen; 19, side view of an imperfect specimen of the usual size. Jeffersonville limestone only. Common.
20-22 Spirifer gregarius. Clapp. 20, pedicle; 21, profile; and 22, brachial valve. Jeffersonville limestone only. Confined to a persistent layer 1 to 2 feet thick about 15 feet below the top called the Spirifer gregarius bed. The silicified pedicle valves can usually be found in the residual soil from the Jeffersonville limestone throughout its area in the county. The brachial valve is rarely preserved.
23 Turbo shumardi. Verneuil. Jeffersonville limestone only. Not very common.
24 Platyceras dumosum. Conrad. Jeffersonville limestone and Beechwood limestone member.

Common and Characteristic Corals of the Jeffersonville Limestone. After Davis, Kentucky Fossil Corals.

Plate 40.

1-2 Zaphrentis prolifica. Billings. 1, view of cup or calyx; 2, side view. Jeffersonville limestone only.
3-4 Blothrophyllum cinctutum. Davis. 3, lower end of a corallum; 4, upper end of the same showing the cup in cup manner of growth. Jeffersonville limestone only.
5-6 Favosites hemisphericus. Troost. 6, view of a specimen in the position of growth; 5, section through a smaller specimen showing the honeycomb structure. Jeffersonville limestone only. Common in the Spirifer acuminatus bed in which whitish silicified specimens with the conical side up are fairly abundant.
7 Cladopora bifurca. Davis. One of many species of this genus of branching corals which are exceedingly abundant in the Jeffersonville limestone.

AGE AND CORRELATION.—Of the species enumerated in the above list 65 occur also in the Columbus limestone of Ohio, 45 occur in the Onondaga limestone of New York, and 27 are common to the respective limestones of the three states. It has long been recognized, therefore, that the Jeffersonville limestone is of the same age as the Onondaga ("Corniferous") limestone of New York and

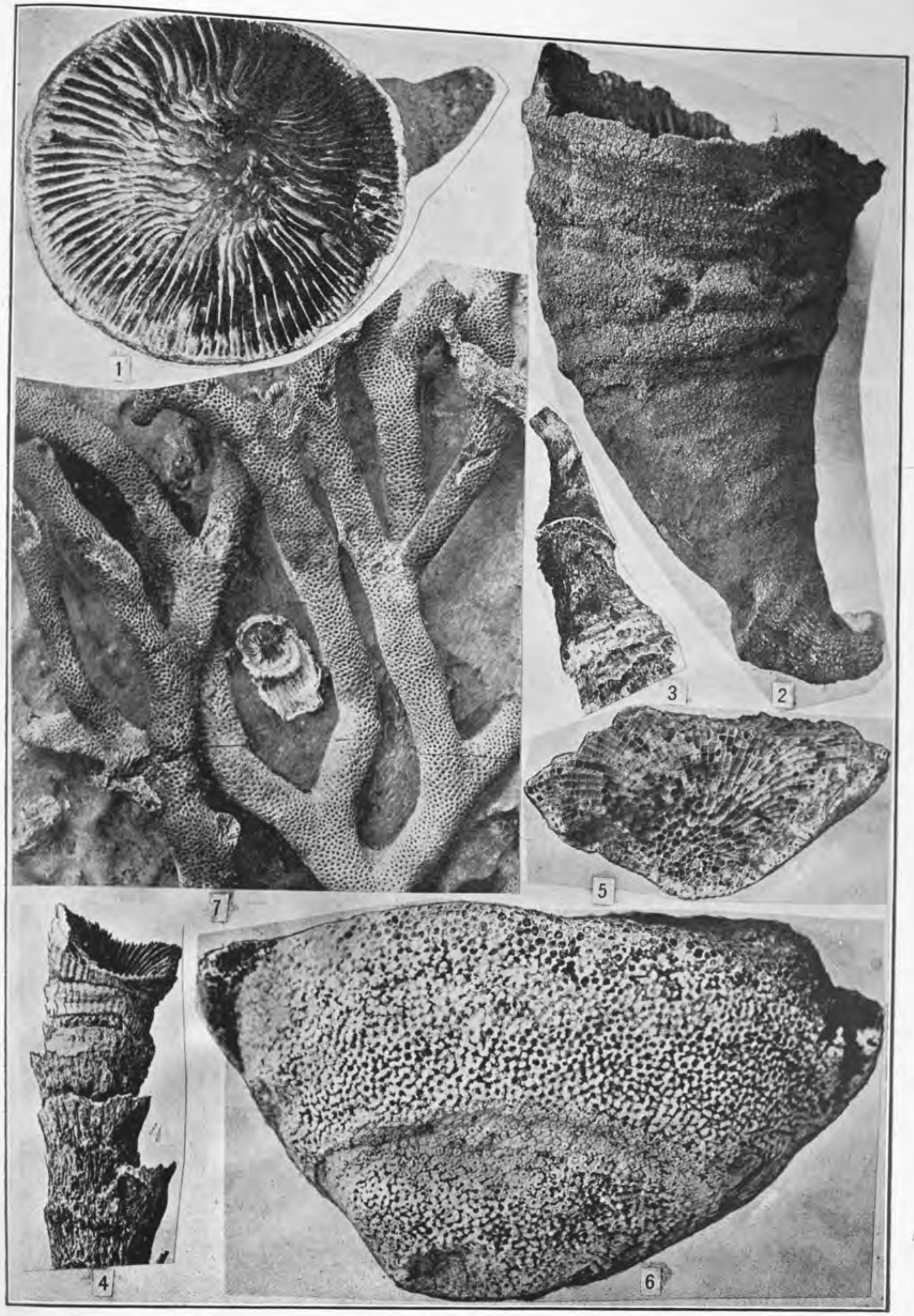

Plate 40.
Common and characteristic fossils of the Jeffersonville limestone. After Davis, Kentucky Fossil Corals.

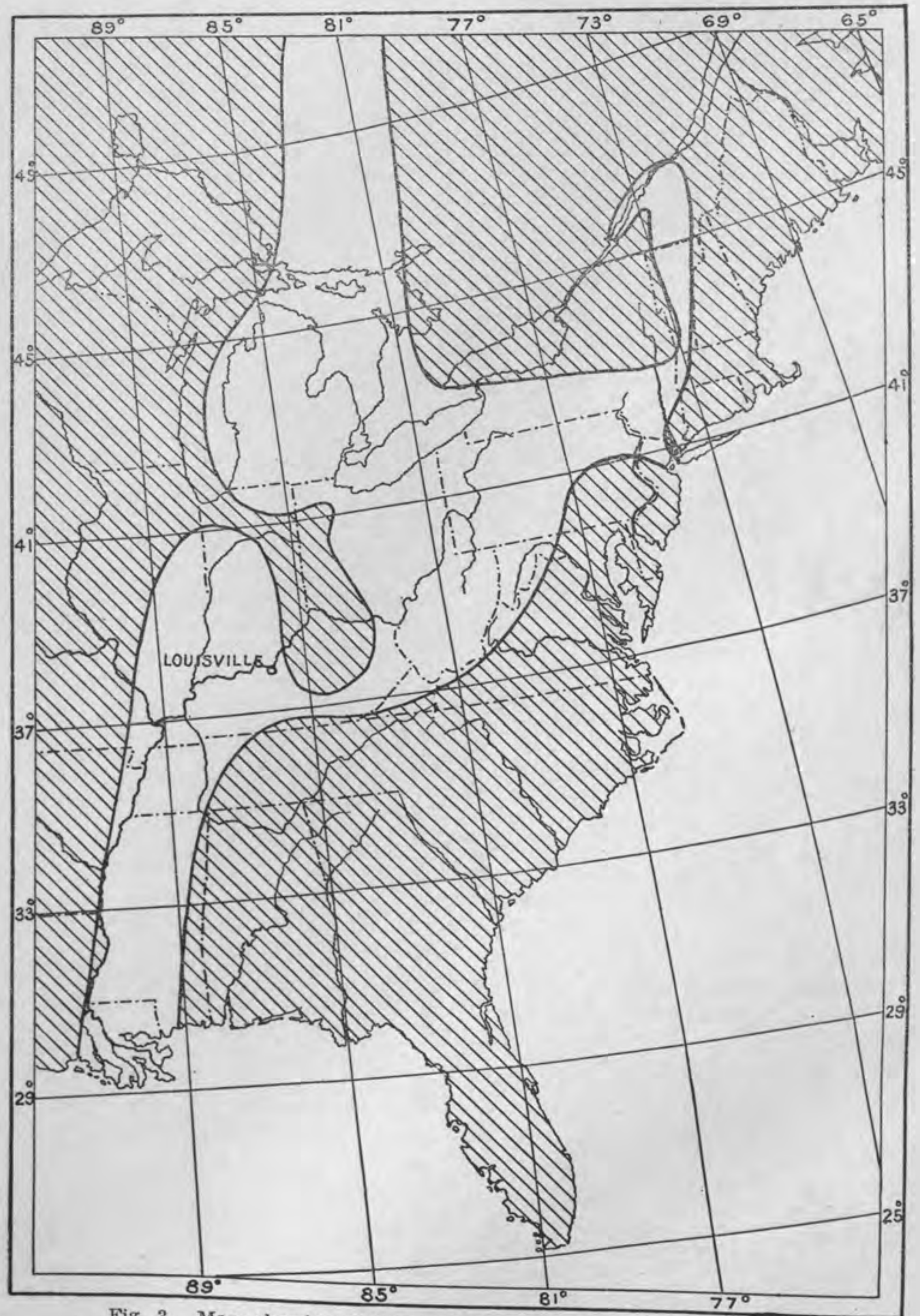

Fig. 3. Map showing the approximate extent of the interior sea of Onondaga ("Corniferous") time in which was deposited the great sheet of limestone known as the Onondaga limestone in New York and Canada, the Columbus limestone in Ohio, the Jeffersonville limestone in Kentucky and Indiana, the Pegram limestone in Tennessee, and the Grand Tower limestone in Illinois. Unshaded area water, shaded area land. Compiled and slightly modified from Stauffer Bull. No. 10, Ohio Geol. Surv., 1909, and from Schuchert Bull. Geol. Soc. Am., No. 20, 1909.

of the equivalents of that limestone in Canada, of the Columbus limestone of Ohio, of the Grand Tower limestone of Illinois, and the Pegram limestone of Central Tennessee. This great limestone sheet is one of the most unmistakable cases of widely extended stratigraphic continuity and equivalence known in the geology of the Eastern United States.

The shape and extent of the interior sea of Onondaga ("Corniferous") time in which the Jeffersonville limestone was deposited is shown in Fig. 3. This map is based upon the known present distribution of the rocks and distinctive fossils of Onondaga age and is, of course, to some extent hypothetical, since the deposits are in some regions inaccessible to observation, and in other regions they have been extensively eroded and their exact present as well as their original limits are therefore undeterminable. The oceanic connections of the interior sea through the Gulf of Mexico, and New York Bay are especially hypothetical, while that through Hudson Bay seems well founded since rocks bearing the Onondaga fauna exist in the immediate neighborhood of the south end of the bay. The assumed connection with the Gulf of Mexico also seems to be justified by the presence in the Jeffersonville and older Devonian deposits of the Mississippi Valley of certain fossils, such as *Stropheodonta perplana* which also occur in the Devonian of Brazil and Bolivia, and of trilobites closely related to South America forms. A water connection with South America making possible migration between the two areas seems to be indicated by such facts of animal distribution. Such oceanic connections as are indicated on the map afforded avenues of migration between the Kentucky region and other parts of the world by which the varied faunal associations of the former were brought about.

Since there is no evidence that the species first appearing in the Onondaga sea originated therein it is assumed that they underwent their evolution from preexisting species in some other parts of the world, probably in the permanent oceans, and migrated from the places of their origin into the interior sea through some of the connecting waters mentioned above.

SELLERSBURG LIMESTONE.

NAME AND DEFINITION.—The Sellersburg limestone is named from Sellersburg, Indiana, about 9 miles northeast of Louisville. The name was applied by Kindle* and included the limestone of distinctive character between the Jeffersonville limestone as already described and the New Albany shale. The Sellersburg is made up of two members of plainly different character, the Silver Creek (hydraulic) limestone member below and the Beechwood limestone member above. Siebenthal† limited the application of the name Sellersburg to the Beechwood member, but as the two distinct beds are both of Hamilton age, a name to include the two, as adopted by Kindle is preferred.

SILVER CREEK LIMESTONE MEMBER.

NAME AND DEFINITION.—The name Silver Creek hydraulic limestone was applied by Siebenthal‡ from Silver Creek, a stream emptying into the Ohio opposite the east end of Sand Island. It reaches its best development along this creek. It includes the dull-gray, fine-grained magnesian limestone lying between the light-gray, shelly, medium-grained limestone of the *Spirifer acuminatus* zone at the top of the Jeffersonville limestone below, and the light-gray, very coarse-grained, crinoidal limestone of the Beechwood member of the Sellersburg limestone above.

DISTRIBUTION.—The Silver Creek limestone is so far as known in outcrop limited in Kentucky to a relatively small area lying along the river bank immediately north of Louisville and extending eastward as a thin layer to the lower part of Beargrass Creek. If it is present farther eastward or northeastward in the general Devonian area its presence has not been surely detected and because of its thinness at its most eastern exposure, as described on a succeeding page, it is considered probable that it does not extend far eastward of Louisville. Its

*Kindle, E. M., Am. Paleontology Bull. No. 12, p. 112, 1899.

†Siebenthal, C. E., Ind. Dept. Geol. & Nat. Res., 25th Ann. Rept., p. 341, 1901.

‡Siebenthal, C. E., loc. cit., p. 345.

Plate 41.
Silver Creek limestone member about 18 inches thick with the Spirifer acuminatus zone of the Jeffersonville limestone below and the Beechwood limestone member above. Hammer rests upon the Spirifer acuminatus bed. Cut on the electric railway on Payne street near Sturgus. Looking northwest.

Plate 42.
Mass of Silver Creek limestone showing chalky appearing chert nodules. Also shows irregular contact with Beechwood limestone. Louisville canal near Pennsylvania Railroad bridge.

extent underground south and southwest of Louisville is of course unknown.

The best display of the member is on the north bank of Ohio River near the point north of the word "of" in the legend, Falls of the Ohio, as shown in Plate 34.

THICKNESS.—At the point just described the Silver Creek member is 16 feet thick. This appears to be the maximum in this vicinity. Southeastward it thins, and in an exposure in the railroad cuts, in the eastern part of Louisville near Sturgus and Payne Streets at a distance corresponding to a point about one-half mile due north of the word, Hill, in the legend, Cave Hill Cemetery, it is only 1½ to 2½ feet thick, as shown on Plate 41. The thickness of this member on the river bank near the south end of the Pennsylvania Railroad (middle) bridge is greater than in the railroad cuts, being perhaps 8 to 10 feet. It could not be determined exactly.

CHARACTER.—The Silver Creek limestone is thick-bedded, dark-gray, fine-grained, low to high magnesian, siliceous and aluminous. It ranges approximately 50 to 60% calcium carbonate, 16 to 35 per cent. magnesian carbonate, 10 to 25 per cent. silica and 2 to 5 per cent. alumina. (See analyses p. 220.) A large part of the silica is probably in the form of chert, of chalky appearance on weathering, which shows as whitish blotches on the face of the layers in which it is present. This is shown on Plate 42. The presence of argillaceous matter in this rock adapts it to use for hydraulic cement when properly treated, hence its common designation "hydraulic limestone" or "cement bed," etc. It has been extensively utilized in the region for the manufacture of natural cement, but owing to the general supplanting of the latter by Portland cement, the use of the Silver Creek rock has been largely discontinued.

FOSSILS.—The Silver Creek limestone is moderately fossiliferous, brachiopods and pelecypods being the most common fossils. A list is given below.

BEECHWOOD LIMESTONE MEMBER.

NAME AND DEFINITION.—The Beechwood limestone member of the Sellersburg limestone is here so named from Beechwood Station on the Louisville and Nashville Railroad. While not exposed at Beechwood it probably underlies that point and its top is exposed in a stream at a point a few rods north of the Shelbyville turnpike one-half mile south of Beechwood, and 1½ miles east of St. Mathews. It includes 2 to 6 or 8 feet of coarse, crinoidal limestone, bounded below by the Silver Creek limestone and above by the New Albany shale.

DISTRIBUTION.—The Beechwood member, although thin, seems to be the most widely distributed of the Devonian limestones. Besides its occurrence on the north bank of the Ohio and in the canal on the south bank, it was observed, immediately beneath the New Albany shale at Lyndon, on Preston Street road at Evergreen Cemetery, and east of the north end of Norton Hills. It appears safe to assume its presence wherever the surface of the country is high enough to reach up to its horizon and it has been mapped accordingly.

The best exposure of the Beechwood member is on Rock Island, in the river northeast of the locks of the Louisville Canal. Here the member, several acres in extent and 5 feet thick, caps the island, around which it is conspicuously exhibited as a ledge.

THICKNESS.—No exposure of both top and bottom of the Beechwood member at the same point was discovered and hence no certainly correct measurement of its thickness was made. About 3 to 4 feet of the lower part of the Beechwood has been exposed in the east end of the Louisville Canal and the lower 4 feet in the electric railroad cut on Payne Street near Sturgus Street, in the eastern part of Louisville. At none of these points is the top of the limestone present, but the general conditions in the near neighborhood of the localities mentioned indicate that not more than a foot or two is absent at the top, so that probably the full thickness does not exceed 6 feet in the vicinity of Louisville. Kindle* gives its range in thickness in Clark County, Indiana, as 5 to 8 feet. His

*Kindle, E. M., Ind. Dept. Geol. & Nat. Res., 25th Ann. Rept., p. 534, 1900.

section at a cement quarry 1½ miles south of Charlestown gives a thickness of 6 feet 8 inches. In the southern part of Jefferson County the thickness is 2 to 3 feet. On Brooks Run 1½ miles south-southeast of the county line at the Norton Hills, the thickness of the Beechwood is 2 feet. At this point both top and bottom are present and exposed.

CHARACTER.—The Beechwood limestone is rather thick-bedded. The lower part tends to a light gray color and a fairly coarsely crystalline texture, while the upper part is of finer grain and of dark gray color. It is full of the joints of crinoid stems which give to some parts a coarsely crystalline appearance. The lower few inches to 1 foot is, in places, at least, separated from the Silver Creek limestone below and the superior part of the Beechwood above by very irregular bedding planes, and the layer of irregular thickness thus set off carries rather abundant black phosphatic nodules having a very smooth surface which gives them the appearance of water worn pebbles. A sample of these pebbles, collected in the electric railroad cut on Payne Street, Louisville, hitherto adverted to, contained nearly 35 per cent. of phosphorus pentoxide. The character of the bedding planes and the black nodules scattered through the lower layer are shown on Plate 43. While the black nodules are much larger and more plentiful in the lower layer, small scattered ones apparently of the same character are present throughout. The nodules are of any size from that of a pin head up to 2 inches or more in longest diameter and the larger ones are of irregular shapes, generally rather flattened and deeply pitted or cavernous. They are black and lustrous on the outside, but vary in character inside from a rusty earthy material to a light gray or dark gray, compact, fine textured calcareous material that resembles the Silver Creek limestone. The nodules are fossiliferous, having small linguloid shells, fragments of bryozoans, crinoid joints, and possibly ostracods. Minute ovoidal or ellipsoidal bodies resembling in size and shape the ostracod genus *Primitia* are very abundant in parts of some of the nodules. In some cases these are arranged in thin layers and in others irregularly distributed throughout a large part of a nodule. Some of these small bodies are spherical and show plainly a concentric lamellar struc-

ture and are pretty certainly oolites, and this suggests the possibility that all are oolitic in origin and character. Most of the ovoidal bodies may be internal casts of ostracods, however. At the top the Beechwood limestone is very sharply and evenly demarcated from the overlying New Albany shale as shown on Plate 44. The upper one-half inch of the limestone immediately below the shale has been largely replaced by pyrite supposedly derived from the shale. In places there is a thin layer of black shale, one-eighth inch thick, below the pyrite layers, which, however, in such cases is also a replacement of limestone deposited upon the thin layer of black sediment. This circumstance may indicate that the deposition of the black shale followed that of the Beechwood limestone without any break in the continuity of sedimentation in the region, though such a strong lithic and faunal change as that from the limestone to the black shale seems more likely to have required considerable time for its consummation.

FOSSILS.—The Beechwood member is moderately fossiliferous, brachiopods, pelecypods, bryozoans and crinoids being the most plentiful forms. The bed is in places crowded with crinoidal joints and on any large exposed surface are many portions of the jointed columns of crinoids and an occasional head. One of the best places to see these is in the river bed at low water on the Indiana side of the river just above the mouth of Silver Creek.

The following lists have been compiled from Nettelroth, Davis, Kindle, Siebenthal, and Hall, to which reference has already been made. The compiled lists have been supplemented and checked by collections made in the survey for the present report. In the case of some forms it is not possible to identify with certainty their source, whether from the Silver Creek or Beechwood member or even from Jeffersonville limestone. Some of the fossils are reported from all three divisions. Not all the forms included in the list have been found in Kentucky, but all are known from the neighboring part of Indiana, where conditions for collecting are better than in Kentucky, and probably all occur in Kentucky also.

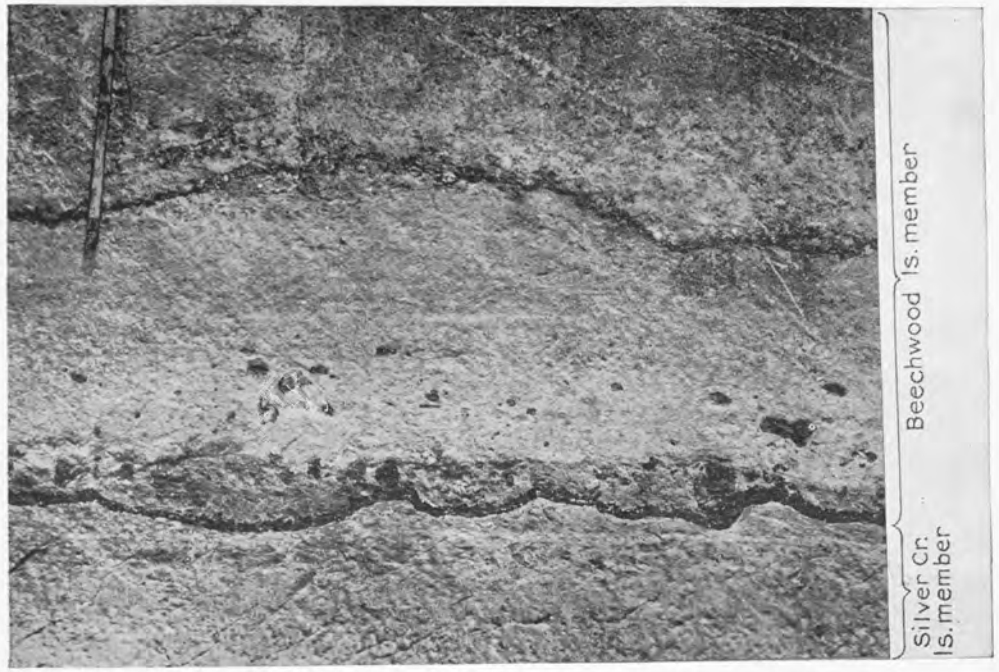

Plate 43.

Irregular bedding in the lower part of the Beechwood limestone and black phosphatic nodules. Louisville canal near Pennsylvania Railroad bridge. Looking north.

Plate 44.

Contact between the Beechwood limestone and the New Albany shale. West end of Louisville canal. Looking south.

The geographic and stratigraphic range of these species is indicated by symbols following the name of the species as given below:

O c reported from Columbus limestone of Ohio.
O d reported from Delaware limestone of Ohio.
O o reported from Olentangy shale of Ohio.
N. Y. o reported from Onondaga limestone of New York.
N. Y. m reported from Marcellus shale of New York.
N. Y. h reported from Hamilton formation of New York.
M h reported from Traverse formation of Michigan (of Hamilton age).
C o reported from Onondaga limestone of Canada.

List of Fossils From the Silver Creek Limestone Member.

Corals.
Zaphrentis sp.?

Bryozoa.
Fenestella sp.?
Lichenalia sp.?

Brachiopods.
Athyris fultonensis. Swallow.=A. vittata.
Atrypa reticularis. Linnaeus. O c, d, N. Y. o, h.
Atrypa spinosa. Hall. O c, d, N. Y. o, h.
Atrypa sub-quadrata. Nettelroth.
Chonetes yandellanus. Hall. O c.?
Cyrtina hamiltonensis. Hall. O c, r, N. Y. o, h.
Cyrtina hamiltonensis var resta. Hall. N. Y. h.
Eunella (Terebratula) lincklaeni. Hall. O c, d, N. Y. h.
Glossina (Lingula) tringulate. Nettelroth.
Meristella haskinsi. Hall. N. Y. h.
Spirifer byrnesi. Nettelroth.
Spirifer fornacula. Hall. O c.
Spirifer iowaensis. Owen. atwaterensis.
Spirifer oweni. Hall.
Spirifer varicosus. Hall. O c, N. Y. o.
Strophodonta concava. Hall. O c, d, N. Y. o, h.
Strophodonta perplana. Conrad. O c, d, N. Y. o, h.
Tropidoleptus carinatus. Conrad. N. Y. m h.

Pelecypods.
Aviculopecten crassicostatus. Hall and Whitfield.
Paracyclas elliptica. Hall.
Paracylas lirata. Conrad.

Gastropods.
Polyphemopsis louisvillae. Hall and Whitfield.

Cephalopods.
Nautilus maximus. Conrad.

The mcre common and characteristic of these fossils are shown in Plate 45.

The geographic and stratigraphic range of these species is indicated by symbols following the name of the species as given below:

O c reported from Columbus limestone of Ohio.
O d reported from Delaware limestone of Ohio.
O o reported from Olentangy shale of Ohio.
N. Y. o reported from Onondaga limestone of New York.
N. Y. m reported from Marcellus shale of New York.
N. Y. h reported from Hamilton formation of New York.
M h reported from Traverse formation of Michigan (of Hamilton age).
C o reported from Onondaga limestone of Canada.

List of Fossils From the Silver Creek Limestone Member.

Corals.
Zaphrentis sp.?

Bryozoa.
Fenestella sp.?
Lichenalia sp.?

Brachiopods.
Athyris fultonensis. Swallow.=A. vittata.
Atrypa reticularis. Linnaeus. O c, d, N. Y. o, h.
Atrypa spinosa. Hall. O c, d, N. Y. o, h.
Atrypa sub-quadrata. Nettelroth.
Chonetes yandellanus. Hall. O c.?
Cyrtina hamiltonensis. Hall. O c, r, N. Y. o, h.
Cyrtina hamiltonensis var resta. Hall. N. Y. h.
Eunella (Terebratula) lincklaeni. Hall. O c, d, N. Y. h.
Glossina (Lingula) tringulate. Nettelroth.
Meristella haskinsi. Hall. N. Y. h.
Spirifer byrnesi. Nettelroth.
Spirifer fornacula. Hall. O c.
Spirifer iowaensis. Owen. atwaterensis.
Spirifer oweni. Hall.
Spirifer varicosus. Hall. O c, N. Y. o.
Strophodonta concava. Hall. O c, d, N. Y. o, h.
Strophodonta perplana. Conrad. O c, d, N. Y. o, h.
Tropidoleptus carinatus. Conrad. N. Y. m h.

Pelecypods.
Aviculopecten crassicostatus. Hall and Whitfield.
Paracyclas elliptica. Hall.
Paracylas lirata. Conrad.

Gastropods.
Polyphemopsis louisvillae. Hall and Whitfield.

Cephalopods.
Nautilus maximus. Conrad.

The mcre common and characteristic of these fossils are shown in Plate 45.

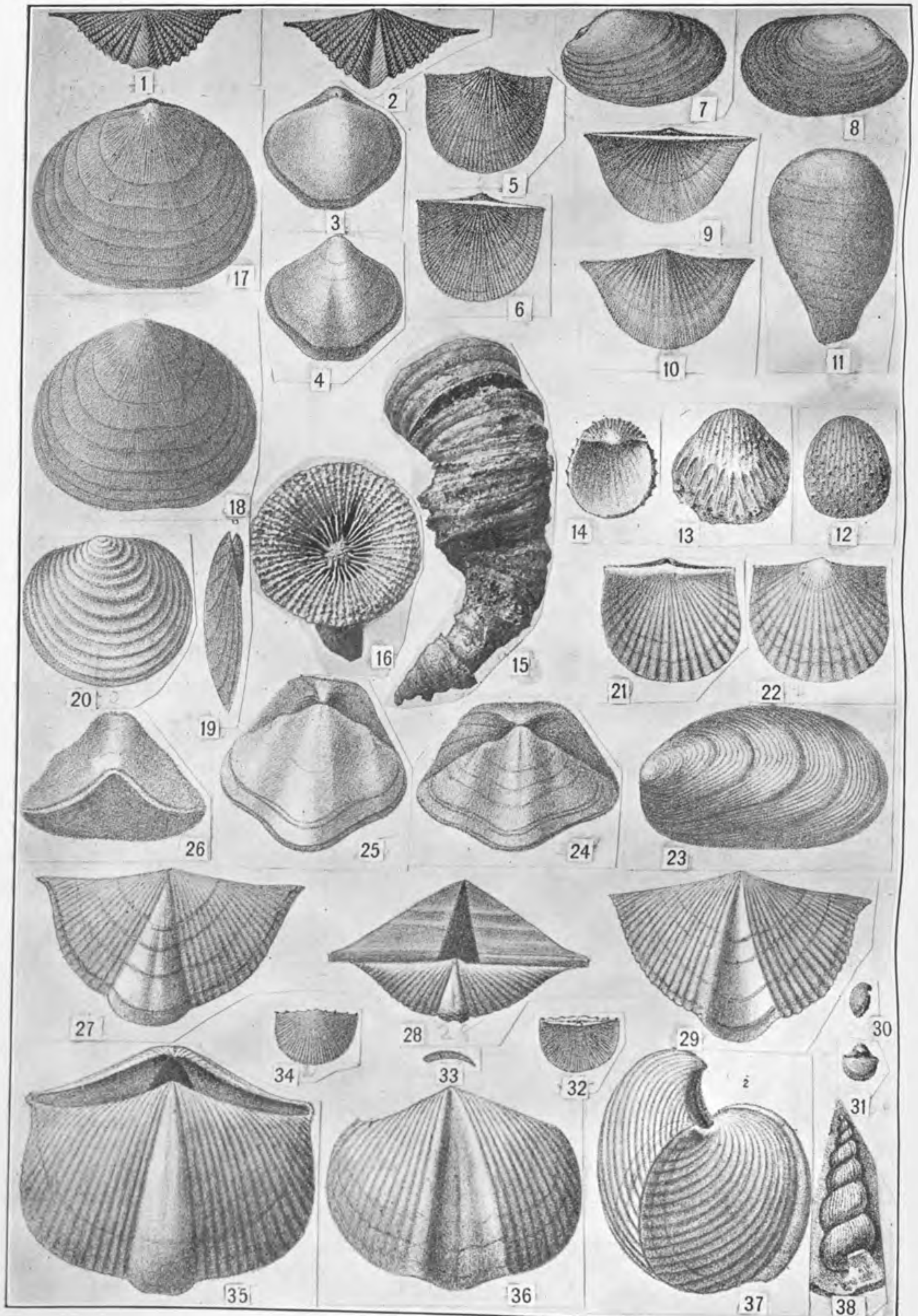

Plate 45.
Fossils from the Sellersburg Limestone. All after Nettelroth.

Fossils From the Sellersburg Limestone. All After Nettelroth. Plate 45.

1-2 Spirifer hobbsi. Nettelroth. 1, brachial; 2 pedicle valve. Beechwood limestone member.

3-4 Athyris fultonensis. Swallow. 3, brachial; 4, pedicle valve. Jeffersonville and Sellersburg limestones. Common.

5-6 Stropheodonta demissa. Conrad. 5, pedicle; 6, brachial valve. Common in the Jeffersonville and Sellersburg limestone.

7-8 Clinopistha antiqua. Meek. 7, left; 8, right valve. Beechwood limestone member.

9-10 Chonetes acutiradiatus. Hall. 9, brachial; 10, pedicle valve. Common in Beechwood limestone member.

11 Gomphocreras turbiniforme. Meek and Worthen. Beechwood limestone member.

12-14 Productella subaculeata cataracta. Hall and Whitfield. 12 and 13, pedicle; 14, brachial valve. Beechwood limestone member. Common. Perfect specimens rare.

15-16 Heliophyllum juvene. Rominger. After Davis. Reported by Davis from the Beechwood limestone member.

17-19 Rhipidomella. (Orthis.) vanuxemi. Hall. 17, brachial; 18, pedicle; and 19, profile view. Sellersburg limestone, common.

20 Paracyclas lirata. Conrad. View of a left valve. Silver Creek limestone member.

21-22 Tropidoleptus carinatus. Conrad. 21, brachial; 22, pedicle valve. Silver Creek limestone member.

23 Modiomorpha concentrica. Conrad. View of a left valve. Beechwood limestone member.

24-26 Pentagonia unisulcata. Conrad. 24, pedicle; 25, brachial; and 26, front view. Beechwood limestone member.

27-29 Spirifer fornacula. Hall. 27, brachial; 28, cardinal; 29, pedicle view. Sellersburg and Jeffersonville limestones.

30-31 Ambocœlia umbonata. Conrad. 30, profile; 31, brachial view. Beechwood limestone.

32-34 Chonetes yandellianus. Hall. 32, brachial; 33, profile; and 34, pedicle view. Silver Creek limestone only. Abundant.

35-37 Spirifer oweni. Hall. 35, brachial; 36, pedicle; and 37, profile view. Silver Creek limestone only. Fairly abundant.

38 Loxonema hydraulicum. Hall and Whitfield. Silver Creek limestone only.

List of Fossils From the Beechwood Limestone Member.

Corals.

Alveolites goldfussi. Billings. N. Y. h.
Alveolites scandularis. Davis.
Antholites speciosus.
Aulacophyllum conigerum. Davis.
Aulopora cornuta. Billings.
Chonophyllum nanum. Davis.
Cladopora alicornis. Davis.
Cladopora gulielmi. Davis.
Cladopora pinguis. Rominger.
Cyathophyllum ethelanum. Davis.
Cyathophyllum insigne. Davis.
Cyathophyllum pustulosum. Davis.
Cyathophyllum scyphus. Rominger. M h.
Cyathophyllum tornatum. Davis.
Cyathophyllum trauthanum. Davis.
Cystiphyllum americanum. Edwards and Haime. C o, N. Y. h.
Cystiphyllum ohioense. Nicholson.
Dendropora alternans. Rominger.
Dendropora neglecta. Rominger.
Dendropora ornata. Rominger.
Dendropora osculata. Davis.
Diphyphyllum (Crepidophyllum) archiaci. Billings. O c, d, N. Y. h.
Drymopora auloporoidea. Davis.
Drymopora frutectosa. Davis.
Favosites cavernosus.
Favosites digitatus. Rominger.
Favosites goodwini. Davis.
Favosites eximus. Davis.
Favosites placenta. Rominger.
Favosites rotundituba. Davis.
Heliophyllum juvene. Rominger.
Heliophyllum infoveatum. Davis.
Michelinia insignis. Rominger.
Michelinia plana. Davis.
Zaphrentis cornalba. Davis.
Zaphrentis explanata. Davis.
Zaphrentis gallicalcar. Davis.
Zaphrentis nettelrothi. Davis.
Zaphrentis nodulosa. Rominger.
Zaphrentis reynoldsi. Davis.
Zaphrentis trigemma. Davis.
Zaphrentis ungula. Rominger.

Crinoids.

Ancyrocrinus bulbosus. Hall. N. Y. h.
Dolatocrinus bulbaceus. Miller and Gurley.
Dolatocrinus greeni Miller and Gurley. O c.
Dolatocrinus tuberculatus. Wachsmuth and Springer.
Gennaeocrinus kentuckiensis. Shumard.
Megistocrinus depressus. Hall. O c, N. Y. h.
Megistocrinus rugosus. Lyon and Casseday. O c.

Brachiopods.

Ambocœlia umbonata. Conrad. O d, N. Y. h.
Athyris fultonensis. Swallow. O c.
Atrypa spinosa. Hall. O c, d, N. Y. o, h.
Camarotoechia sappho. Hall. O d, N. Y. h.
Centronella glansfagea. Hall. O c, N. Y. o.
Chonetes acutiradiatus. Hall. O c, N. Y. o.
Crania sheldoni. White. C bordini. Hall and Whitfield.
Cyrtina hamiltonensis. Hall. O c, d, N. Y. o, h.
Cyrtina hamiltonensis var. recta. Hall. N. Y. h.
Delthyris (Spirifer) sculptilis. Hall. N. Y. h.
Orbiculoidea (discina) doria. Hall. O d, N. Y. h.
Pentagonia (Meristella) unisulcata. Conrad. N. Y. o, h.
Pholidostrophia iowaensis. Owen. O c, d, N. Y. o, h.
Pholidostrophia spinulicosta. Hall. O c, d, N. Y. h.
Rhipidomella (Orthis) goodwini. Nettelroth.
Rhipidomella (Orthis) livia. Billings. O c, d, N. Y. o.
Rhipidomella (Orthis) vanuxemi. Hall. O c, d, N. Y. h.
Schizophoria (Orthis) striatula. Schlotheim. O c, N. Y. o.
Schuchertella Chemungensis arctistriatus. Hall.=Streptorhynchus.
arctostriata. Nettelroth. O d, N. Y. h.
Spirifer audaculus. Conrad. O d, N. Y. h.
Spirifer hobbsi. Nettelroth.
Spirifer iowaensis. Owen=Sp. atwaterana. Nettelroth.
Spirifer macconathi. Nettelroth.
Spirifer oweni. Hall.
Spirifer segmentum. Hall.
Spirifer varicosus. Hall.
Stropheodonta concava. Hall. O c, d, N. Y. o, h.
Stropheodonta demissa. Conrad. O c, d, N. Y. o, h.
Stropheodonta perplana. Conrad. O c, d, N. Y. o, h.

Pelecypods.

Aviculopecten princeps. N. Y. o, h.
Clinopistha antiqua. Meek. O c.
Clinopistha striata. Nettelroth.
Clinopistha subnasuta. Hall and Whitfield.

Grammysia gibbosa. Hall and Whitfield.
Limoptera cancellata. Hall
Modiomorpha affinis. Hall. N. Y. h.
Modiomorpha alta. Conrad. N. Y. h.
Modiomorpha charlestownensis. Nettelroth.
Modiomorpha concentrica. Conrad. O c, N. Y. h.
Modiomorpha mytiloides. Conrad. N. Y. h.
Nucula herzeri. Nettelroth.
Nucula neda. Hall and Whitfield.
Nucula niotica. Hall and Whitfield.
Paracyclas elongata. Nettelroth.
Paracyclas ohioensis. Meek.
Ptychodesma knappiana. Hall.
Yoldia valvulus. Hall and Whitfield.

Gastropods.
Bellerophon leda. Hall.
Euomphalus sampsoni. Nettelroth.
Loxonema hamiltoniae. Hall. N. Y. h.
Loxonema hydraulicum. Hall and Whitfield.
Loxonema laeviusculum. Hall. O c.
Loxonema rectistriatum. Hall.
Platyceras conicum. Hall. N. Y. o, h.
Platyceras dumosum. Conrad. O d, N. Y. h.
Platyceras echinatum. Hall. N. Y. h.
Platyceras rarispinum. Hall. O c.
Platystoma lineatum. Conrad. O c, N. Y. o, h.

Pteropods.
Tentaculites scalariformis. Hall. O c, d, N. Y.

Cephalopods.
Gomphoceras oviforme. Hall. N. Y. h.
Gomphoceras turbiniforme. Meek and Worthen.

Ostracods.
Kirkbya sp.?

Trilobites.
Dalmanites calypso. Hall and Clarke.
Phacops rana. Green. O d, N. Y. h.
Proetus macrocephalus. Hall. N. Y. h.

A number of the more important and characteristic species are illustrated in Plates 45 and 46.

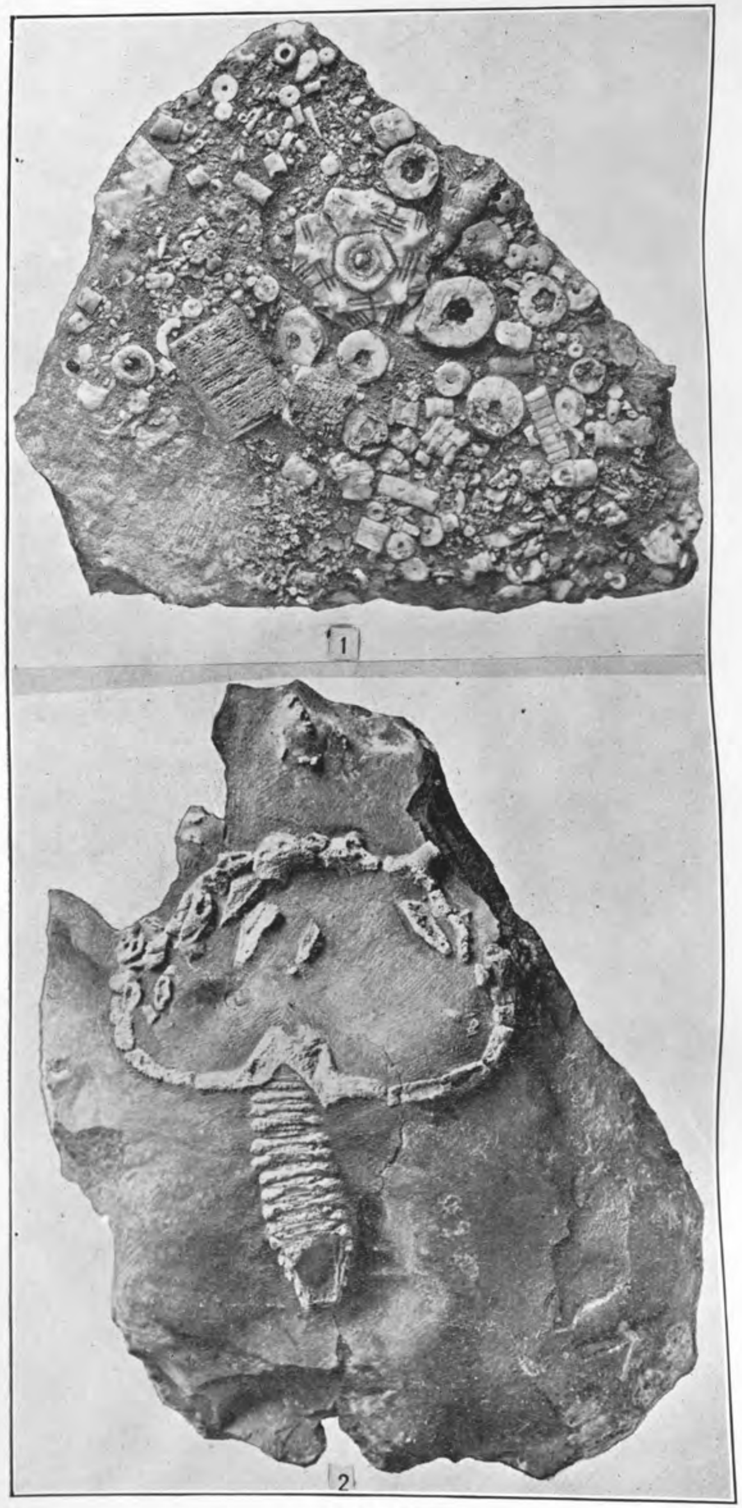

Plate 46.
Crinoids of the Beechwood limestone.

Crinoids of the Beechwood Limestone Member.

Plate 46.

1 Piece of limestone made up largely of crinoidal joints "Buttons." Basal plates of a crinoid, probably Dolatocrinus tuberculatus. Wachsmuth and Springer. Central plate, place of attachment to stem as shown in Fig. 2. Beechwood limestone member. Illustrates the abundance of crinoidal remains to the presence of which is due the popular designation, Encrinal limestone.

2 Piece of limestone with section of head of a species of Dolatocrinus with upper part of stem attached. From top surface of Beechwood limestone on Rock Island.

AGE AND CORRELATION OF THE SELLERSBURG LIMESTONE.

It appears from the above lists that there are present in the Sellersburg limestone 18 species of fossils not recorded as occurring below the Marcellus shale. Most of these are not recorded from rocks below the Hamilton formation of New York. Likewise none of the number is recorded below the Delaware limestone of Ohio which is correlated with the Hamilton. These circumstances, combined with the further facts that the Sellersburg is underlain immediately by beds of Onondaga ("Corniferous") age and is succeeded by beds of Genesee age establishes a strong probability of the Hamilton age of the Sellersburg limestone, although it is not claimed that the latter represents the whole of the Hamilton. Neither the lithic character nor fossils of the Sellersburg indicate that it represents any part of the Marcellus shale, which lies between the Onondaga ("Corniferous") and Hamilton in New York, and if the Marcellus is not represented it follows that a stratigraphic hiatus exists between the Jeffersonville and the Sellersburg measured by the Marcellus shale of New York.

NEW ALBANY SHALE.

NAME AND DEFINITION.—The New Albany shale was named by Borden* from the city of New Albany, Indiana, in the vicinity of which the shale is well exposed. The original form was New Albany black slate, but later practice has been to omit the word black, as superfluous. The New Albany includes all the distinctly black fissile shale, about 100 feet thick, sharply demarcated below by the Beechwood limestone, and above by the soft, green clay shale known as the New Providence shale.

DISTRIBUTION.—In areal distribution the New Albany shale is nearly limited to the southwestern one-third of the county. The only exception is a patch of about 3 square miles in the vicinity of Lyndon where a thin veneer of the lower few feet of the shale is present. The main area of outcrop is between the Southern Railway west of Buechel and the northeast base of the Knobs, extending westward to Highland Park and eastward to Okolona. It, however, underlies the Knob region and the alluvial flats between the Knobs and Ohio River as shown by wells drilled to it for gas in the vicinity of Kosmosdale and by its presence along the sides of the Louisville Canal below the gravel at the bottom of the alluvium. The shale can best be seen along the Indiana bank of the river between the mouths of Silver Creek and Falling Run. The best display is at the mouth of the latter. (See Plate 47.)

THICKNESS.—The thickness of the New Albany in this region is universally accepted as about 100 feet. On the authority of Borden† the thickness is 104 feet at the base of the "Knobs" at New Albany as determined by well borings. According to the writer's own observations, at least 60 feet of black shale below the overlying Rockford limestone is exposed along Falling Run and on the river bank at the mouth of that creek. At the Kentucky and Indiana (western) Bridge, 1 mile above the mouth of Falling Run, at least 25 feet of shale is exposed and there is known to be 15 feet more below the exposed shale. As there is a dip of 30 feet per mile or there-

*Borden, W. W., Fifth Ann. Rept. Ind. Geol. Survey, p. 158, 1874.

†Borden, Wm. W., Fifth Ann. Rept. of the Geol. Survey of Indiana, p. 158, 1874.

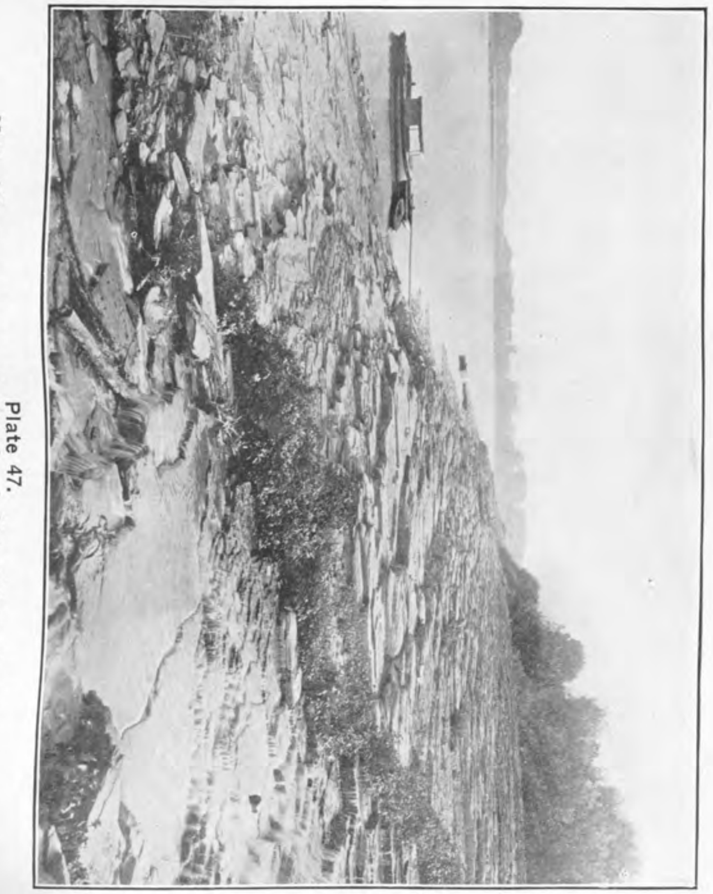

Plate 47.
New Albany shale on the bank of Ohio River at the mouth of Falling Run, New Albany, Indiana. About 1 mile west of Sand Island. Looking west. This outcrop includes about the middle 25 or 30 feet of the New Albany.

abouts westward, most of the thickness exposed at this point must underlie the shale exposed at the mouth of Falling Run, so that by this method of calculation the total thickness of the New Albany shale approximates 100 feet. This thickness can therefore be accepted as close to the truth.

CHARACTER.—The New Albany is almost wholly a thinly fissile, densely black shale. Its fissility is revealed, however, only on weathering and its black color is fully preserved only in the fresh condition. A perfectly fresh cut shows a very compact, homogeneous and densely black mass. On prolonged weathering the shale splits into thin laminae, the original black color of which becomes gray on the surface, but preserves its black color or turns brownish within. (See Plate 47 for the general aspect of the partially weathered shale.) At the base of the black shale is a layer of pyrite about one-half inch thick which has originated subsequently to the deposition of the strata. The origin of this pyrite layer is explained under Historical Geology. The great body of the black shale is probably composed mostly of very fine particles of argillaceous matter, quartz and mica. Lime carbonate is present generally in the lower 15 feet and not improbably throughout, probably in small quantity, but sufficient to produce feeble effervescence on treating the shale with acid. Pyrite in small crystals or particles is generally distributed throughout the stratum and misleads the ignorant into the belief that it is gold. Pyrite is a compound of iron and sulphur, of bright yellow color, known as iron sulphide and, owing to its deceptive appearance, has received the common designation, "Fools' gold." In that part of the formation between about 10 and 13 feet above the bottom are a number of calcareous sandstone layers which contain so large a proportion of carbonate of lime as to effervesce very freely under acid. These sandstone layers are interbedded in black shale and vary from mere laminae up to 1½ inches in thickness. They are principally made up of very small angular quartz grains of irregular shape, but contain a little muscovite and pyrite, in addition to all of which is a proportionally large quantity of carbonate of lime probably present as the cementing medium of the other constituents. The sandstone layers are ripple marked. Associated with the

sandstone layers are an abundance of fossil plant stems and fragmentary fish remains. Just above the sandstone layers is about 1 foot of sheety brown shale very largely composed of *Sporangites,* minute disc-shaped bodies of amber color to which the shale owes its brownish color. These bodies are the fossil spore cases of plants related to the modern lycopods which have similar spore cases.

A foot or two above the zone of sandstone layers and 15 feet above the bottom of the New Albany shale is a layer 8 inches thick of a compact, very fine-grained gray rock possibly of an arenaceous clayey composition, and about 15 feet higher or 30 feet above the bottom of the black shale is a 3-inch layer of crumbly green shale. With the exception of the two layers just described and the calcareous sandstone layers, the New Albany is, so far as exposed in this region, a densely black shale. The black color is chiefly due to carbonaceous matter which is present in such quantity as to burn upon liberation by heating the shale. Fishermen report that they often use the shale for heating purposes on chilly days. The results of determinations of the kinds and quantities of carbonaceous substances of the shale are stated under the head of Economic Geology. Some of the plant stems occurring in the shale are carbonized to the condition of coal of which thin laminae occur. At the top of the formation is a layer of earthy material, about 6 inches thick, containing numbers of nodules supposed from similar occurrences elsewhere at the same horizon to be rather highly phosphatic. These nodules weather white on the outside but are brownish within. They are generally ovoidal and of all sizes up to 4 inches in longest diameter.

FOSSILS.—The New Albany shale like the supposed equivalent black shale elsewhere in the eastern part of the Central States is sparsely fossiliferous in respect to both individuals and species. An exception is the *Sporangites* which are extremely abundant in many layers of the shale and common throughout.

A list of species collected by the writer or reported by Kindle and others from this or neighboring regions in Kentucky and Indiana follows:

List of Fossils From the New Albany Shale.

Plants.
- Paleophychus newalbanaense. Duden.
- Paleophychus lineare. Duden.
- Parenchymophycus asphalticum. Duden.
- Pseudobornia? (Calamites) inornata? Dawson.
- Sporangites huronensis. Dawson.
- Sporangites radiatus. Duden.

Brachiopods.
- Chonetes lepidus. Hall.
- Leiorhynchus quadricostatus. Vanuxem.
- Lingula melie. Hall.
- Schizobolus concentricus. (Vanuxem.)

Pteropods.
- Styliola fissurella. Hall.

Of the forms listed above none of the brachiopods except the *Lingula* have been found or recorded to the writer's knowledge more than 5 feet above the bottom of the New Albany. The *Lingula* extended at least 30 feet above. The *Schizobolus* was not found by the writer more than 6 inches above the bottom. The *Pseudobornia?* is abundant in the calcareous sandstone zone associated with fish remains. A specimen was found also in a chunk thrown out of the Louisville Canal which probably came from near the bottom since the same piece contains specimens of *Schizobolus.* The *Parenchymophycus, Palaeophychus* and *Sporangites radiatus* probably occur at a horizon about 25 to 30 feet above the bottom.* The *Styliola* must also occur near the bottom of the shale since it is reported only in association with some of the brachiopods which seem to be restricted to that horizon.

AGE AND CORRELATION.—Until recent years the New Albany shale in its entirety has been correlated with the Genesee shale of New York and the Huron shale of Ohio. Of late that correlation has been questioned by Ulrich, who maintains that only the lower few feet containing *Schizobolus concentricus, Leiorhynchus quadricostatus,* etc., known elsewhere only from the Genesee shale, is of Genesee age. The upper 85 to 90 feet of the New Albany,

*Duden, Hans. Some Notes on the Black Slate or Genesee shale of New Albany, Indiana: Ind. Dept. Geol. & Nat. Res., 21st Ann Rept., pp. 108-119, 1896.

including as a basal bed the calcareous sandstone zone, Ulrich assigns to the Carboniferous system on evidence that cannot be fully stated here. One important item, however, is the presence of *Lingula melie,* which is a common form of the Sunbury shale in the Carboniferous of Ohio. He also argues from considerations of a more general nature such as a widespread movement of elevation and a long period of dry land between the deposition of the lower part of the shale ascribed to the Genesee and the deposition of the upper 90 feet which is regarded as Carboniferous. If the latter supposition is correct, there is a stratigraphic hiatus in the New Albany about 10 feet above the bottom measured by over 5,000 feet of shale and sandstone of Portage and Chemung age in Central Pennsylvania, and this too without any irregularity or discordance of bedding to mark the contact of the Genesee and the much younger carboniferous parts of the New Albany, if the upper part is indeed carboniferous. Such a situation is, however, paralleled by the contact of the Louisville and Jeffersonville limestones previously described.

In view of the paucity of fossil evidence bearing on the subject and its apparently indecisive character, the writer prefers at present not to take a decided stand on the question of the age of the upper 90 feet or so of the New Albany shale, although strongly inclined to maintain its Upper Devonian age. It seems to be equivalent to the Ohio shale of central Ohio, to part at least of the Chagrin formation of Eastern Ohio, and the Genesee Portage and Chemung formations of New York.

This subject is a large one which can not be fully discussed here, but it is only fair to state the fact that a controversy exists concerning it.

CARBONIFEROUS SYSTEM.

The formations of the Carboniferous system in this general region are divided into two series, the Mississippian series below and the Pennsylvanian series above. The Mississippian series, which means the same as lower Carboniferous or "sub-Carboniferous," is named from the Mississippi Valley region where the series is typically developed as limestone of wide geographic extent; the Pennsylvanian series means the same as upper Carboniferous, or as the "Coal Measures," and is named from Pennsylvania where the series is well developed and widely known in connection with coal mining operations. Nearly all the coal east of the Rocky Mountains is in the Pennsylvanian series, but there is some coal in the Mississippian series of the Appalachian Valley from Pennsylvania to Tennessee.

The Mississippian series of this region is subdivided into the following groups and formations, the latter differing in character and name in different localities as shown in the following table:

Table Showing Groups and Formations of the Mississippian Series.

Mississippi Valley.		Jefferson County, Kentucky.	
Groups.	Formations.	Groups.	Formations.
Chester.		Not present.	
	Ste. Genevieve ls.		Not present.
Meramec.	St. Louis ls.	Meramec.	Not present.
	Spergen ("Salem") ls.		Spergen ("Salem") ls.
	Warsaw ls.		Warsaw ("Harrodsburg.") ls.
Osage.	Keokuk ls.	Osage ("Knobstone.")	Holtsclaw ss.
			Rosewood shale.
			Kenwood ss.
	Burlington ls.		New Providence shale.
Kinderhook.	Several formations of shale, limestone and sandstone of local distribution.	Not present in Jefferson County unless represented by upper part of New Albany shale or lower part of New Providence shale.	

As shown in the above table the only rocks of the Carboniferous system present in Jefferson County belong in the middle part of the Mississippian series and are divided into the following formations, named in ascending order: New Providence shale, Kenwood sandstone, Rosewood shale, Holtsclaw sandstone, Warsaw ("Harrodsburg") limestone and Spergen ("Salem" or "Bedford") limestone. The strata from the New Providence shale to the Holtsclaw sandstone inclusive constitute the "Knobstone group," the designation in general use in this region up to the present time.

UNCONFORMITY BETWEEN THE NEW ALBANY AND NEW PROVIDENCE SHALES.

According to Ulrich there is a small stratigraphic gap between the New Albany and New Providence shales due to the absence in this region of the Ridgetop shale which in northwestern Tennessee intervenes between the Chattanooga shale, representing some part of the New Albany, and the shale in the Tennessee locality which is regarded as the representative of the New Providence. Furthermore in Indiana the Rockford limestone, generally about 2 feet thick and persistent, is present between the New Albany and New Providence shales, but in Kentucky this bed is absent. The Rockford has generally been correlated with some part of the Kinderhook group of Missouri and Illinois, and it is probable that the Ridgetop shale is of the same age. The New Providence shale, however, seems properly to be correlated with the Burlington limestone, which is the lowest formation of the Osage group, the latter being next in succession above the Kinderhook. If, then, the New Providence rests upon the New Albany without the intervention of beds of Kinderhook age, as the writer is inclined to believe is the case, there is a hiatus between the New Albany and New Providence measured by the Kinderhook group elsewhere. In other words, the situation would be the same as if no rocks were deposited in this part of Kentucky during the time that the Kinderhook group, as a maximum 150 feet thick, was being deposited in Missouri. If, however, it be established that the upper part of the New Albany is of Mississippian age it would doubtless be regarded as the partial or possibly as nearly the whole equivalent of the Kinderhook, thus reducing materially the magnitude of the hiatus. The layer of phosphatic nodules between the New Albany and New Providence previously described, was formed in this period of very slow deposition or of non-deposition in the region.

NEW PROVIDENCE SHALE.

NAME AND DEFINITION.—The New Providence shale was named by Borden* from New Providence, Clarke County, Indiana. It was defined by him as including the lower 80 to 120 feet of the "Knobstone group." In Jefferson County the New Providence type of shale as described by Borden extends from the New Albany shale up to a persistent zone of sandstone or sandstone layers in shale described beyond as the Kenwood sandstone.

DISTRIBUTION.—The New Providence outcrops on the sides of the knobs in the vicinity of Iroquois and Jacobs Parks, extending from their bases nearly to their tops which are capped by the Kenwood sandstone. It outcrops lower on the sides of the Knobs farther southward, and in the level spaces between them. Its top passes beneath the overlying strata at the north bases of Mitchell and Jefferson Hills and at the base of the hill at Pleasure Ridge. It also outcrops in the upper part of the valley on Crane Run and of the run just east of Johnsontown. It extends about half way up the side of South Park Hill and Norton Hills.

There is an excellent exposure of nearly the whole thickness on the south end of Kenwood Hill. This is shown on Plate 48. Another partial exposure visible from the railroad is on the side of the hill east of Hunters Trace where the shale was formerly dug for use in the old brick plant at that place. The shale is also quarried and can be seen at the brick works at Coral Ridge. Another good exposure where the shale contains an unusual number of thin ferruginous and highly fossiliferous limestone layers is in the northwest side of Button Mould Knob 1 mile south of the county from Norton Hills.

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*Borden, Wm. W., Ind. Dept. Geol. & Nat. Res., 5th Ann Rept., p. 161, 1874.

THICKNESS.—The thickness of the New Providence in Jefferson County as nearly as can be determined is 150 to 160 feet.

CHARACTER.—The New Providence is almost wholly a soft, greenish clay shale, so loosely cemented as to readily disintegrate to a clay on weathering. Material from a weathered bank still preserving the lamination of the shale can easily be moulded by the hand like clay. The principal constituents of the shale are approximately silica, 60%, alumina 20%, iron oxide 4½ to 6½%, magnesium carbonate 4%, and potassium oxide 5%. (See analyses Nos. G-3,654, 3,655 and others in the table.) This shale is being successfully utilized for brick at Coral Ridge.

In the middle part of the New Providence there are locally a number of thin layers of limestone. Some of these are made up principally of crinoidal joints. Some have been largely converted into iron oxide presumably by replacement of the original calcium (lime) carbonate by iron oxide. On the northwest side of Button Mould Knob, a celebrated fossil locality 1 mile south of the county south of the Norton Hills, the fossiliferous and ferruginous limestone layers extend through the middle 50 or 60 feet of the formation, and on the west side of Kenwood Hill near the north end the fossiliferous limestone layers occupy about the middle 20 feet and are crowded with fossils. However, at the south end of Kenwood Hill, less than a mile from the north end, where nearly the whole formation is exposed, as shown in Plate 48, but little limestone is present and not a single fossil could be found, although the conditions are ideal for revealing them if present in the rocks. Similar fossiliferous limestone layers imbedded in soft green and reddish fossiliferous shale, in all 2 or 3 feet thick, are exposed in the bed of the creek by the roadside one-half mile south of Fairdale. These three localities are the only ones where the fossiliferous limestone was seen. On the southeast side of Button Mould Knob where a part of the fossiliferous limestone zone is exposed, neither limestone nor fossils were found, although the locality is not more than one-fourth mile distant from the highly fossiliferous exposure on the northwest side of the knob.

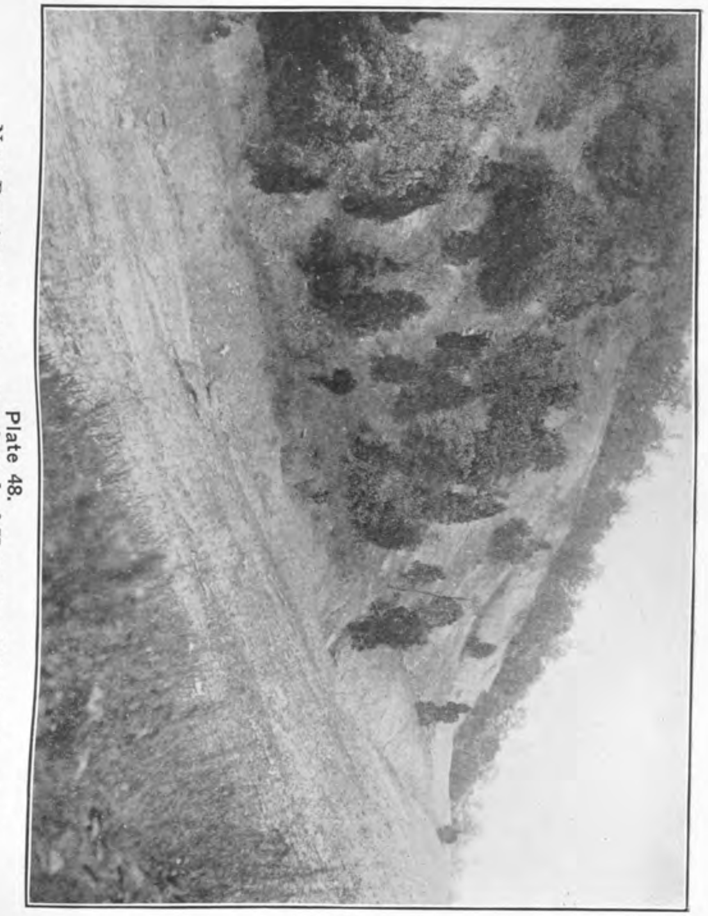


Plate 48.
New Providence shale. South end of Kenwood Hill. Looking east. Owing to the soft character of the shale, it has disintegrated to clay on the outcrop. The scattered chunks are sandstone bowlders from the Kenwood sandstone which caps the hill shown in the left of the view.

These examples suffice to show the local character of the fossiliferous limestone layers in the New Providence. One other feature of the formation remains to be mentioned, namely, the abundant iron carbonate concretions. These are practically confined to the upper half of the New Providence. They are of nodular shape, generally ovoidal or discoidal, red on the outside and changing gradually to bluish gray inward. They are of nongranular texture. A few small ones were found containing specimens of *Conocardium* as a nucleus. The nodules range in size from that of a small marble to 1 foot or more in the longest diameter. A specimen from Clarke County, Indiana, several miles north of Jefferson County, contained 49.72% carbonate of iron* together with considerable quantities of silica, calcium (lime) and magnesium carbonate. These nodules are arranged in bands parallel to the bedding of the shale, usually a number of them in the space of a few feet. There is more or less of a gradation from these bands of nodules to the thin, ferruginous layers seemingly derived from layers of limestone by the process of replacement of calcium carbonate by iron carbonate This ferruginous material is not rich enough in iron nor is the quantity sufficient for commercial development.

FOSSILS.—As already indicated the New Providence is highly fossiliferous, but the fossils are almost wholly confined so far as the Jefferson County region is concerned, to the thin, ferruginous limestone layers occurring locally in the middle part of the shale. A few fossils likewise have been found in the iron carbonate nodules in the upper half of the shale. No fossils, however, have been found in the shale itself except in immediate association with the limestone layers. In an exposure of about 150 feet of shale without limestone layers at the south of Kenwood Hill, comprising about the full thickness of the formation, only a crinoid joint or two could be found on prolonged search, although all the conditions were ideal for liberation and exposure of fossils if any were present in the shale. Where present, however, fossils are very abundant, crinoids, bryozoans and brachiopods being the most common forms.

*Borden, Wm. W., 5th Ann. Rept. of the Geol. Survey of Indiana, p. 162, 1874.

From various localities both within the county and in the immediately surrounding region, especially, however, from Button Mould Knob, the following species have been obtained:

List of Fossils From the New Providence Shale in and Near Jefferson County.

Sponge spicules?

Corals.
- Amplexus fragilis. White and St. John.
- Amplexus sp.
- Amplexus? sp.
- Cladochonus aff. gracilis. Keyes.
- Cladochonus aff. longi. Rowley.
- Cyathaxonia arcuata. Weller.
- Cyathaxonia cynodon. Rafinesque and Clifford.
- Cyathaxonia sp.
- Cyathaxonia? n. sp.
- Favosites valmeyerensis? Weller.
- Monilipora amplexa. Rowley.
- Palæacis cavernosa. Miller.
- Palæacis? sp.
- Striatopora aff. carbonaria. White.
- Trochophyllum verneuillanum. Milne-Edwards and Haime.
- Triplophyllum centralis. (Milne-Edwards and Haime.)
- Triplophyllum cliffordana. (Milne-Edwards and Haime.)
- Triplophyllum? declinis. (Miller.)
- Triplophyllum sp.

Crinoids.*
- Actinocrinus 1 sp.?
- Agaricocrinus 2 sp.
- *Amphoracrinus.
- Barycrinus 3 sp.
- *Cactocrinus 1 sp.
- Catillocrinus tennesseeae. Shumard.
- Cyathocrinus 6 sp.
- Eretmocrinus yandelli.
- Euryocrinus 1 sp.
- *Forbesiocrinus, nobilis type.
- *Gilbertsocrinus cf. tenuiradiatus. Meek and Worthen.
- Halysiocrinus perplexus. Shumard.
- Halysiocrinus sp.

*List of crinoids quoted from Springer. Springer, Frank, The Crinoid Fauna of the Knobstone formation: Proc. U. S. Nat. Mus., vol. 41, pp. 175-206, 1911.

- Megistocrinus.
- *Mespilocrinus 2 sp.
- *Metichthyocrinus tiaraeformis. Hall.
- *Metichthyocrinus clarkensis. Miller and Gurley.
- *Orophocrinus cf. stelliformis. Owen and Shumard.
- *Platycrinus americanus. Owen and Shumard, or yandelli Owen and Shumard. discoid form.
- Platycrinus burlingtonensis? Owen and Shumard.
- Platycrinus cf. granosus.
- Platycrinus planus. Owen and Shumard.
- Platycrinus sculptus. Hall.
- Platycrinus sp.?
- Platycrinus verrucosus. White.

  Elongate or erect forms.
- *Platycrinus cf. yandelli. Owen and Shumard. discoid form.
- Scaphiocrinus 1 sp.
- Schizoblastus sp.
- Schizoblastus decussata.
- Stemmatocrinus trautscholdi. Wachsmuth and Springer.
- Synbathocrinus angularis. Miller and Gurley.
- Synbathocrinus robustus. Shumard.
- Taxocrinus.
- Wachsmuthicrinus 2 sp.

Bryozoa.
- Chainodictyon? sp.
- Cystodictya americana. Ulrich.
- Cystodictya lineata. Ulrich.
- Cystodictya pustulosa. Ulrich.
- Fenestella compressa. Ulrich.
- Fenestella regalis. Ulrich.
- Fenestella triserialis. Ulrich.
- Fenestella sp.
- Fistulipora sp.
- Lioclema punctatum? Hall.
- Meekopora? aperta. Ulrich.
- Polypora sp.
- Ptilopora cylindracea. Ulrich.
- Rhombopora angustata. Ulrich.
- Rhombopora elegantula. Ulrich.
- Rhombopora incrassata. Ulrich.
- Rhombopora sp.
- Stenopora.
- Streblotrypa major. Ulrich.
- Thamniscus divaricans. Ulrich.
- Thamniscus sculptilis. Ulrich.

Brachiopods.
- Brachythyris suborbicularis. Hall.
- Chonetes planumbonus Meek and Worthen. var.
- Chonetes shumardianus. de Koninck.
- Cliothyridina aff. glenparkensis. Weller.
- Productus semireticulatus. Martin.
- Ptychospira sexplicata. White and Whitfield.
- Pustula n. sp.
- Pustula punctata. Martin.
- Rhipidomella oweni. Hall and Clarke.
- Schuchertella aff. lens. White.
- Spirifer aff. floydensis. Weller.
- Spirifer aff. logani. Hall.
- Spirifer aff. moorefieldanus. Girty.
- Spirifer aff. vernonensis. Swallow.
- Spiriferina subelliptica. McChesney.

Pelecypods.
- Paleoneilo sp.
- Posidoniella? sp.

Gastropods.
- Platyceras sp.

Cephalopods.
- Goniatites sp.

Trilobites.
- Brachymetopus sp.
- Griffithides sp.

Ostracoda.

The more common or the characteristic fossils of the New Providence are shown on Plate 49.

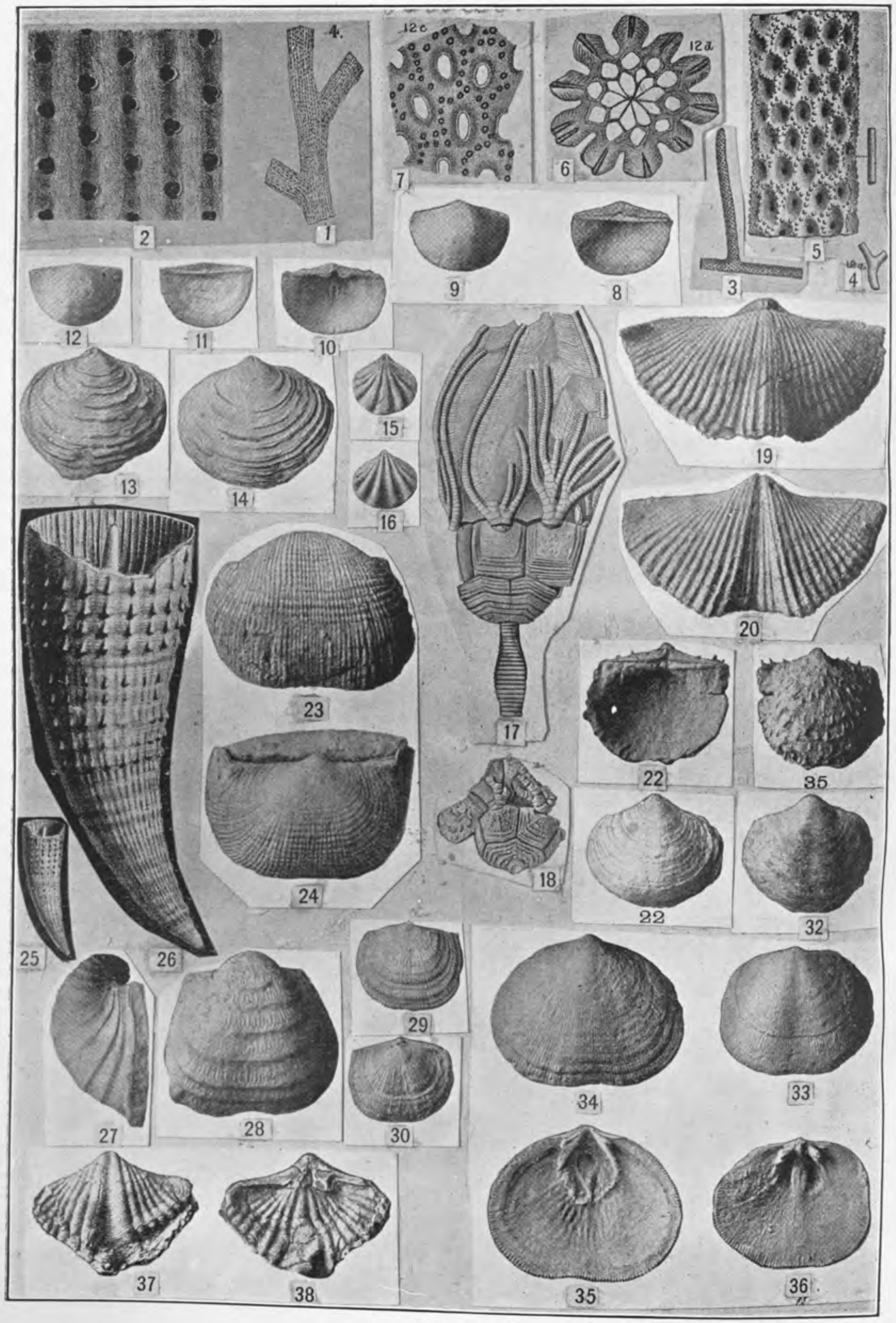


Plate 49.
Fossils of the New Providence shale.

Fossils of the New Providence Shale.
Plate 49.

1-2 Cystodictya lineata. Ulrich. 1, view of a part of a branch natural size; 2, portion of the same enlarged, showing the shape and arrangement of the cell mouths and the linear ridges separating them. Common bryozoan of the Osage and Meramec groups. New Providence shale to Spergen limestone.

3-7 Rhombopora incrassata. Ulrich. After Ulrich. 3 and 4, fragments natural size and enlarged 12 times; 6, transverse section; 7, tangential section.

8-9 Chonetes planumbona. Meek and Worthen. After Weller. 8, brachial; 9, pedicle valve. New Providence shale. Common at Button Mould Knob and Kenwood Hill.

10-12 Chonetes shumardanus. De Koninck. After Weller. 10, interior or a pedicle valve, such specimens common; 11, brachial; and 12, pedicle valve. New Providence shale to Holtsclaw sandstone. Fairly abundant at Kenwood Hill and Button Mould Knob.

13-14 Athyris hannibalensis. Swallow. After Weller. 13, brachial; 14, pedicle view. New Providence shale only.

17-18 Platycrinus sculptus. Hall. After Wachsmuth and Springer. This is a fine example of a crinoid "Stone lily," the stem of which furnishes the "buttons so abundant at Button Mould Knob and Kenwood Hill. This specimen was not obtained at Button Mould Knob but detached plates of the basal parts are common there showing that it lived in the sea covering this region in New Providence time.

19-20 Spirifer vernonensis. Swallow. After Weller. 19, brachial; 20, pedicle valve. This or a very similar form occurs in the New Providence shale at Kenwood Hill and Button Mould Knob.

21-22 Strophalosia cymbula. Hall and Clark. After Weller. 21, pedicle; 22, brachial valve. New Providence shale.

23-24 Productus fernglenensis. Weller. After Weller. 23, pedicle; 24, cardinal view of a valve, showing the reticulated ornamentation. This or a very similar form present in the New Providence of this region and listed as Productus semireticulatus.

25-26 Cyathaxonia cynodon. Edwards and Haime. After Edwards and Haime. Common cup coral of the New Providence shale at Button Mould Knob and elsewhere. The slender cone in the center of the cup is a characteristic feature.

27-28—Echinoconchus (Pustula) alternatus. Norwood and Pratten. After Weller. 27, profile; 28, pedicle view. This or a similar form occurs in the New Providence shale and is listed as Pustula punctata.

29-30 Schuchertella lens. White. After Weller. 1, pedicle; 2, brachial valve. New Providence shale.

31-32 Chothyridina glenparkensis. Weller. After Weller. 31, brachial; 32, pedicle view. This or a similar form occurs in the New Providence shale.

33-36 Rhipodomella oweni. Hall and Clarke. After Weller. 33, brachial; 34, pedicle valve; 35, interior of pedicle; 36, interior of brachial valve. New Providence shale only. Abundant at Button Mould Knob and Kenwood Hill.

37-38 Spiriferina subelliptica. McChesney. After Weller. 37, pedicle; 38, brachial valve. New Providence shale. Common at Button Mould Knob and Kenwood Hill. Specimens doubtfully referred to this species occur in the Rosewood shale and Holtsclaw sandstone.

AGE AND CORRELATION.—Concerning the age and correlation of the New Providence, Geo. H. Girty writes as follows:

"The New Providence shale contains a fauna very different from the Burlington fauna or indeed from any of the typical faunas of the Mississippi Valley section, and its correlation with the Burlington limestone is determined partly by other evidence than the relatively small proportion of its species that occur in and are restricted to the Burlington. The correlation rests in large part on the faunal change that marks the passage from the New Providence shale to the overlying arenaceous beds of the 'Knobstone,' and on the fact that the fauna of the latter has a fairly distinctive Keokuk facies.

"In determining the geologic age of the New Providence shale it is necessary to consider the relations of its fauna not only to that of the Burlington limestone, but to that of the Kinderhook and that of the Keokuk as well. Of the species found in the New Providence shale a considerable number are known from that formation alone or at least are not known in the typical Kinderhook, Burlington, or Keokuk faunas of the Mississippi Valley. It is this fact in large measure that makes the relationship to those of the New Providence faunas so obscure. To the typical Kinderhook fauna, that found at Burlington and Kinderhook, the fauna of the New Providence shale is only remotely allied, and of this relationship, at least, no discussion is needed. Professor Weller was at one time inclined to correlate the New Providence shale

with the Fern Glen formation, and he mentions a few identical or equivalent species: *Amplexus rugosus*, *Monilipora crassa*, corresponding species of *Cyathaxonia*, corresponding species of *Zaphrentis*, *Pentremites decussatus*, and corresponding species of Rhipidomella. To these a few more may be added: *Favosites valmeyerensis?*, *Cyathaxonia arcuata*, and *Ptychospira sexplicata*. Regarding the last, however, though Weller in his recent monograph gives the range as Kinderhook (it occurs in the Fern Glen) and possibly Lower Burlington, I know it in the Boone limestone, possibly as late as the Keokuk.

"Anyone familiar with the Fern Glen fauna could not but be reminded of it while studying the fauna of the New Providence shale; the resemblances merely suggest a relationship, but do not prove that there is one nor that it is very close. On the contrary, Professor Weller has stated to me orally his impression that the Fern Glen fauna may, in some sections, range above the horizon of the Fern Glen formation. Furthermore, some authors have shown a disposition to class the Fern Glen not with the Kinderhook, as does Professor Weller, but with the Osage. With such a classification I am inclined to agree, and indeed I am not at all satisfied that the Fern Glen does not in fact represent the Lower Burlington limestone. The evidence for correlating the New Providence shale with the Burlington limestone will shortly be given; it does not, however, seem to me to show clearly that the period of formation of the New Providence shale does not include Fern Glen time as well as Burlington time. Indeed when we consider that our paleontologic evidence is derived mainly from the upper half of the formation, it is not impossible that the Fern Glen, and even the typical Kinderhook, may be represented in the lower half from which at present fossil evidence is wanting.

"The Keokuk element in the New Providence fauna appears at first considerable, but its significance diminishes greatly on examination. A number of species that are found in the New Providence shale, of which *Brachythyris suborbicularis* is an example, occur also in the Keokuk limestone, but many of these are known in the Burlington as well as in the Keokuk so that as between those two formations the evidence of these species is nil.

Another Keokuk factor in the New Providence fauna consists of 15 species of bryozoans that are regularly carried in the literature as of Keokuk age. These species form part of the bryozoan fauna described by Mr. Ulrich from Kings Mountain tunnel in Eastern Kentucky and identified by him as Keokuk. Of the 15 species that compose this phase of the New Providence fauna, nine are known only at Kings Mountain and six are known both at Kings Mountain and at other localities that certainly represent Keokuk time, one even being Chester. The fauna associated with these Bryozoa at Kings Mountain tunnel is unknown or little known, and the true interpretation of the occurrence of the same species in the New Providence shale may be, not that the New Providence shale is Keokuk, but that the beds at Kings Mountain tunnel are Burlington, since that is the age which the New Providence shale seems to represent. Or it may be that the bryozoans have a long range and that the rocks at one locality are of one geologic age and those at another, of another. Apparently the trend of this bryozoan evidence can not be rightly interpreted until the age of the Kings Mountain locality is better known.

"After thus properly discounting most of the Keokuk evidence of the fossils found in the New Providence shale, there remains only one form, that cited as *Spirifer aff. logani,* which contains any considerable suggestion of the Keokuk facies. *S. logani* is on record only from Keokuk horizons, but not only is the present identification not definite, but I have a specimen that certainly seems to be identifiable with *S. logani,* from a locality in Oklahoma that certainly seems to be identifiable as Kinderhook (St. Joe), or at least basal Burlington. Thus examined, the force of the Keokuk affinities of the New Providence fauna shows not that the geologic age is, but at most that it may be, Keokuk.

"A conclusion, at least a tentative conclusion, that the New Providence shale is not Keokuk, is suggested by the crinoidal element which is fortunately more than commonly rich in the fauna. These crinoids, ten species of them, unmistakably come from the New Providence shale and, according to Springer, they are unmistakably of Lower Burlington type. Aside from the crinoids, however, the New Providence fauna contains little evidence

of weight pointing solely to Burlington age. It is true that *Cladochonus longi, Monilipora amplexa,* and *Striatapora carbonaria* are on record as from the Burlington alone, but not only are the identifications more or less in doubt, but of the corals, even more than of the Bryozoa, can it be truly said that a working knowledge is lacking.

"On the whole, a fairly satisfactory conclusion can be reached that the New Providence shale is of Burlington age, but this conclusion rests chiefly on the evidence of the crinoids, on the fact that a distinct faunal change occurs at the top of the formation, and on the fact that the succeeding fauna has a much more clear and unequivocal Keokuk facies. Aside from the crinoid element, the New Providence fauna contains little that is, according to our present knowledge, distinctive. Many of its species are found in neither the Burlington nor Keokuk faunas of the type section, some are found in both the Burlington and Kinderhook faunas of the type section, and the remainder are, for various reasons, more or less disqualified as to their evidence in correlation. Certain elements in the fauna suggest that the Fern Glen horizon may be represented in the New Providence, but with the Fern Glen fauna completely amalgamated with the Lower Burlington fauna—if indeed the Fern Glen is not itself Lower Burlington. Of the typical Kinderhook the New Providence fauna contains not a trace, but, as the lower part of the formation is unfossiliferous, there is a possibility that the Kinderhook, too, may be represented in it. As, however, the lower part of the New Providence where no fossils have been found is of the same lithologic character as the upper, there is an inherent improbability that it is of a different geologic age."

KENWOOD SANDSTONE.

NAME AND DEFINITION.—The name Kenwood sandstone is here introduced from Kenwood Hill, 7 miles south of Ohio River at Louisville, for sandstone and shale beds of the Osage group immediately above the New Providence shale and forming the upper 30 feet of the hill. The Kenwood is limited above by the Rosewood shale, which is not present on Kenwood Hill. About the upper 10 feet of the Kenwood is also wanting there. The lower layer of the formation at the type locality is shown on Plate 50.

DISTRIBUTION.—The Kenwood sandstone is persistent throughout the Knob region of Jefferson County and southward in Kentucky and in the river bluffs of the adjacent part of Indiana. It caps Kenwood Hill and Jacobs Park Hill where it is fairly well displayed, and near the south boundary of the county outcrops at the base of the Knobs. It outcrops high up on the slopes of South Park and the Norton Hills and caps Button Mould Knob where it is unusually thick bedded and contains a larger proportion of sandstone than elsewhere. It forms the cap rock, 40 feet thick, of Jacobs Park Hill where its basal layer shows at the sharp angle on the road at the south end of the Park and where abundant large bowlders and some outcropping layers are displayed at the circle at the north end of the park. Its presence can everywhere be detected by the abundance of sandstone debris or by the outcropping edges of sandstone layers which occur neither in the New Providence shale below nor in the Rosewood shale above. It is the source of the sandstone cobbles and bowlders to be seen throughout the Knob region at the foot of the slopes or extending some distance up their sides.

THICKNESS.—The Kenwood sandstone has a constant thickness of 40 feet throughout the county.

CHARACTER.—At most localities the Kenwood sandstone is composed of thin sandstone layers alternating with shale, but at a few points the sandstone becomes rather massive and includes a larger proportion of the whole. Such points are the north end of the Norton Hills where it has been quarried on a small scale and on the top of Button Mould Knob about 1 mile southeast of

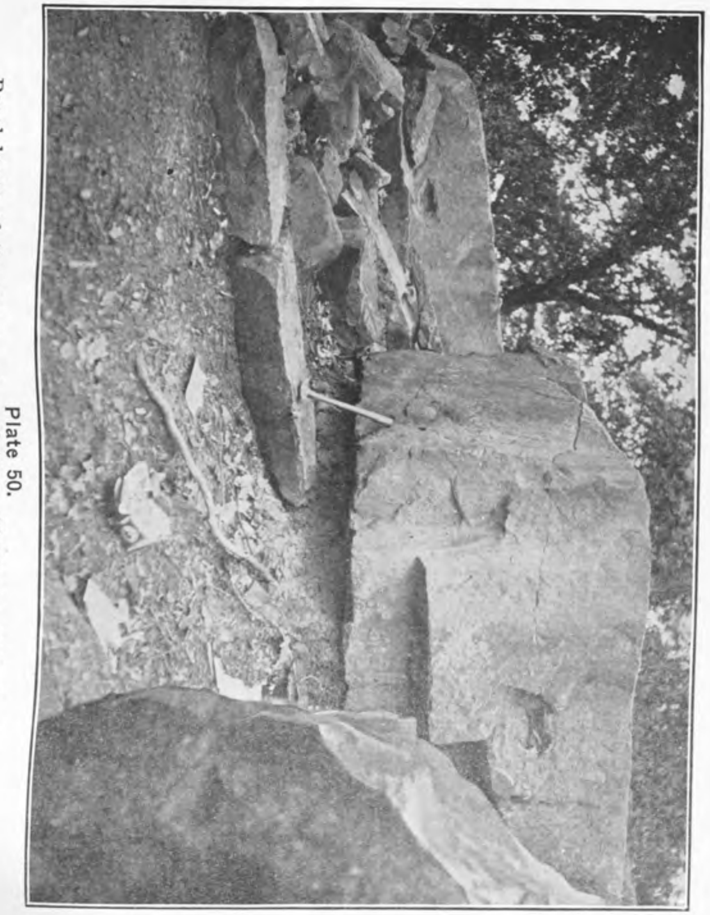


Plate 50.
Basal layer of the Kenwood sandstone. Kenwood Hill, 30 feet below the top. Looking north.

Coral Ridge. On Button Mould Knob the lower 25 feet consists of a massive layer of sandstone about 10 feet thick below 10 feet of shale in the middle and another sandstone layer 5 or 6 feet thick at the top. The formation probably extends to the top of the Knob, but the upper 15 feet is not exposed.

The prevailing character of the formation is indicated by the following section:

Partial Section of the Kenwood Sandstone in the Stream Near the Road About Two Miles Southwest of Fairdale.

	Ft.	In.
Rosewood shale:		
17. Shale		
Kenwood sandstone:		
16. Sandstone, chocolate, hard, fine-grained		3
15. Shale, blue	2	
14. Sandstone, blue, fine-grained	2	
13. Shale, blue		8
12. Sandstone, reddish, calcareous?		3
11. Shale, blue, calcareous nodules	2	6
10. Sandstone, bluish, fine-grained		4
9. Shale, blue	1	3
8. Sandstone, rusty		2
7. Shale, blue	4	
6. Sandstone, rusty		2
5. Shale, blue	5	
4. Sandstone, bluish, fine-grained with iron carbonate nodules up to 1 ft. in diameter (turtle stones.)		8
3. Shale, blue	1	6
2. Sandstone, iron carbonate nodules		2
1. Shale, blue	2	6
	23	5

The sandstone layers seem to be almost wholly composed of very small quartz grains bound by a ferruginous cement. Occasionally small flakes, apparently mica, are present. The sandstone is greenish when fresh, but rusty when weathered. The quartz grains are angular or subangular and range in size from .02 to .2 mm. in diameter, most of them being .06 to .08 millimeter in diameter.

The shale interbedded with the sandstone is similar in aspect to the shale composing the great body of the Rosewood shale next to be described.

FOSSILS.—Fossils, which are very scarce, were found in the Kenwood at only one place, the north end of Jacobs Park Hill, where a few specimens of a *Productus* were obtained.

AGE AND CORRELATION.—The age and correlation of the Kenwood are discussed in connection with the Rosewood shale and Holtsclaw sandstone with which the Kenwood is closely associated.

ROSEWOOD SHALE.

NAME AND DEFINITION.—The name Rosewood is here introduced for that part of the Osage ("Knobstone") group bounded below by the Kenwood sandstone and above by the Holtsclaw sandstone. The name Rosewood is from Rosewood, Indiana, opposite Kosmosdale, Rosewood being located on the outcrop of the shale. It replaces the indefinite designation "Knob shale" hitherto in use.

DISTRIBUTION.—The Rosewood shale makes up the main body of the Knobs south of Louisville, where it forms most of the slopes of the Knobs. Southward in Bullitt County the formation slopes downward until at West Point its top is at about railroad level. The whole formation is exposed on the road west from Brooks, 2½ miles southeast of Coral Ridge, where the road ascends the steep east slope of the ridge. Other points where a large part of the formation is well displayed are on the old road just west of Holtsclaw Hill and on the new cut road descending from Jefferson Hill to the head of Bearcamp Run.

THICKNESS.—The thickness of the Rosewood shale is very uniformly about 190 feet in the county.

CHARACTER.—The Rosewood shale is bluish-gray, unevenly fissile and siliceous. Its approximate composition is 68% silica, 14% alumina, none to 5½% calcium (lime) carbonate, 4% iron oxide, and 3% potassium oxide. Complete analyses are contained in the table, p. 238. About 30 feet below the top is a bed of soft, fine-grained sandstone 5 feet thick. About 70 feet below the top in the section west of Brooks previously mentioned, are a number of thin limestone lenses with which are associated a few ferruginous nodules. In these limestone streaks, in the ferruginous nodules, and in the including shale, fossils are rather plentiful. This ferruginous zone seems to be about 20 feet thick, the limestone lenses, etc., being in the lower 10 feet. The shale under discussion is characterized by peculiar curved, whitish markings 1/16 to 1/8 inch wide, of uncertain origin and nature, but which suggest worm trails or the impressions of fucoid stems. These forms are very abundant in the upper half of the shale and are apparently confined to that part. They are mentioned as fossil worm tracks in descriptions of this shaly part of the Rosewood in Clark County, Indiana,* and possibly have a considerable areal distribution.

FOSSILS.—The Rosewood is moderately fossiliferous in the 30 feet extending from 70 to 100 feet below the top; in other parts no fossils were found. A list of those collected from the fossiliferous zone west of Brooks, is given beyond.

AGE AND CORRELATION.—This subject is discussed on a succeeding page.

HOLTSCLAW SANDSTONE.

NAME AND DEFINITION.—The name Holtsclaw is here introduced for the upper formation of the Osage ("Knobstone") group and takes the place of "Knob sandstone" that has been used by some authors. The name is from Holtsclaw Hill 2 miles southwest of Coral Ridge in the southern part of the county and applies to a comparatively thin sandstone lying between the Rosewood shale and the Warsaw limestone.

DISTRIBUTION.—The Holtsclaw sandstone is present only in the knobs and ridges, near their tops, in the southwestern part of the county. In the part of Bullitt County just east of Kosmosdale and West Point, and in Indiana to the west of those places it is absent, and the Rosewood shale extends up to the Warsaw ("Harrodsburg") limestone.

The Holtsclaw is very generally exposed on the steep slopes near the tops of the Knobs or in the heads of ravines, and almost everywhere there is no difficulty in identifying it and with it the top of the Rosewood shale. One of the best exposures is in the road southwest from

*Borden, Wm. W., Loc. cit., p. 165.

Mitchell Hill shown on Plate 51, and another is a clean exposure in the steep east side of the ravine north of the road on Jefferson Hill, about one-fourth of a mile northeast of the road intersection shown on the map a short distance east of the word "Hill."

THICKNESS.—The prevailing thickness of the Holtsclaw is about 20 feet, but it varies from 15 to 25 feet.

CHARACTER.—The Holtsclaw sandstone is a bluish-gray or buffish, rather loosely cemented, soft and easily disintegrated, very fine-grained, thick to massive bedded stratum as shown on Plate 51. It is not everywhere sharply demarcated from the underlying shale, the passage from the one to the other being commonly gradational rather than abrupt, and in such cases it is difficult to determine the position of the boundary. In the road section west of Brooks previously referred to, the lower 15 feet of the Holtsclaw is separated by shale into 2 beds of sandstone, each about 5 feet thick.

FOSSILS.—The Holtsclaw sandstone is moderately fossiliferous in places, brachiopods being the most common forms. Such as have been collected are listed below:

Because of their close relationship and for convenience of discussion the fossils from the Kenwood, Rosewood, and Holtsclaw are here listed in juxtaposition.

Plate 51.
Holtsclaw sandstone. Road southwest from Mitchell Hill, about ¼ mile west of the summit. Shows tendency to exfoliate or weather off diagonally to the bedding. Looking northwest.

Lists of Fossils From the Kenwood Sandstone, Rosewood Shale, and Holtsclaw Sandstone.

1. List from the Kenwood Sandstone.

Brachiopods.
Productus wortheni. Hall.

2. List from the Rosewood Shale.

Fucoid? whitish markings like worm trails. Abundant.

Corals.
Amplexus fragilis. White and St. John.
Cladochonus aff. longi. Rowley.
Triplophyllum sp.

Crinoid (Blastoid.)

Bryozoa.
Cystodictya sp.
Fenestella several species.
Hemitrypa sp.
Pinnatopora sp.
Rhombopora several species.

Brachiopods.
Brachythyris suborbicularis. Hall.
Chonetes shumardanus. de Koninck.
Chonetes sp.
Cliothyridina parvirostris. Meek and Worthen.
Cyrtina aff. burlingtonensis. Rowley.
Dielasma sp.
Productus aff. arcuatus. Hall.
Productus crawfordsvillensis? Weller.
Productus wortheni? Hall.
Productus ovatus.
Reticularia pseudolineata. Hall.
Rhynchopora beecheri? Greger.
Schuchertella (aff.?) chemungensis. Conrad.
Spirifer floydensis. Weller.
Spirifer rostellatus. Hall.
Spiriferina subelliptica? McChesney.

Pelecypods.
Conocardium sp. a.
Conocardium sp. b.
Crenipecten? sp.
Cypricardinia aff. scitula. Herrick.
Leda? sp.
Paleoneilo aff. bedfordensis. Meek.

Gastropods.
- Bembexia n. sp.
- Bucanopsis? sp.
- Oxydiscus sp.
- Platyceras sp.

Cephalopods.
- Orthoceras sp.

Trilobites.
- Phillipsia? sp.
- Brachymetopus elegans?

3. List from the Holtsclaw Sandstone.

Fucoid.

Corals.
- Cladochonus aff. gracilis. Keyes.
- Cladochonus sp.
- Triplophyllum sp.

Bryozoa.
- Batostomella? sp.
- Cystodictya lineata? Ulrich.
- Cystodictya sp.
- Dichotrypa? sp.
- Fenestella several species.
- Hemitrypa sp.
- Lioclema sp.
- Polypora several species.
- Rhombopora? sp.
- Stenopora sp.

Brachiopods.
- Athyris lamellosa. l'Eveille.
- Brachythyris suborbicularis. Hall.
- Chonetes shumardanus. de Koninck.
- Chonetes sp.
- Crania n. sp.
- Dielasma aff. fernglenensis. Weller
- Eumetria verneuiliana. Hall.
- Lingulidiscina sp.
- Orthotetes keokuk. Hall.
- Productus arcuatus. Hall.
- Productus crawfordsvillensis. Weller.
- Productus n. sp.

- Productus aff. ovatus. Hall.
- Productus aff. parvus. Meek and Worthen.
- Productus sp.
- Productus wortheni. Hall
- Pustula alternata? Norwood and Pratten.
- Reticularia pseudolineata. Hall.
- Reticularia sp.
- Rhynchopora beecheri. Greger.
- Spirifer crawfordsvillensis. Weller.
- Spirifer floydensis. Weller.
- Spirifer keokuk. Hall.
- Spirifer montgomeryensis. Weller.
- Spirifer rostellatus. Hall.
- Spirifer tenuicostatus. Hall.
- Spiriferina subelliptica? McChesney.
- Spiriferina sp.
- Syringothyris texta. Hall.

Pelecypods.
- Aviculipecten sp.
- Conularia sp.
- Cypricardinia aff. scitula. Herrick.
- Myalina keokuk? Worthen.

Gastropods.
- Platyceras sp.

Trilobites.
- Phillipsia sp.

Illustrations of some of the more common and characteristic of these fossils are given on Plate 52.

Fossils of the Rosewood Shale and Holtsclaw Sandstone. All After Weller.

Plate 52.

1-3 Productus wortheni. Hall. 1, pedicle; 2, profile; 3, brachial view. Kenwood sandstone to Holtsclaw sandstone. Common.

4-6 Cyrtina burlingtonensis. Rowley. 4, brachial; 5, pedicle; 6, profile view. Rosewood shale.

7-9 Syringothyris textus. Hall. 7, brachial; 8, pedicle; and 9, profile view. Holtsclaw sandstone only.

10-11 Spirifer rostellatus. Hall. 10, brachial; 11, pedicle view. Rosewood shale and Holtsclaw sandstone only.

12 Reticularia pseudolineata. Hall. Pedicle valve. Rosewood shale and Holtsclaw sandstone only.

13 Brachythyris (Spirifer) suborbicularis. Hall. Pedicle valve. New Providence shale to Holtsclaw sandstone.

14-15 Rhynchopora beecheri. Greger. 14, pedicle; 15, brachial valve. Holtsclaw sandstone and perhaps Rosewood shale also.

16-17 Orthotetes (Derbya) keokuk. Hall. 16, pedicle; 17, brachial valve, both partly exfoliated showing interior markings. Holtsclaw sandstone only.

18-19 Spirifer crawfordsvillensis. Weller. 18, pedicle; 19, brachial valve. Rosewood shale and Haltsclaw sandstone.

AGE AND CORRELATION.—The faunas of the formations listed above are made up of forms characteristic of the Keokuk limestone mingled with others that have come up from lower formations. The most important of the characteristic Keokuk forms are *Orthotetes keokuk, Productus wortheni, Reticularia pseudolineata Rhynchopora beecheri, Spirifer rostellatus, Spirifer keokuk* and *Syringothyris texta. Productus wortheni* is present in the Kenwood sandstone and, according to Girty, who identified the fossils, is not known below the Keokuk. All the other characteristic forms above mentioned occur in the Holtsclaw sandstone at the top of the group. These facts are regarded as sufficient to establish the Keokuk age of the three formations.

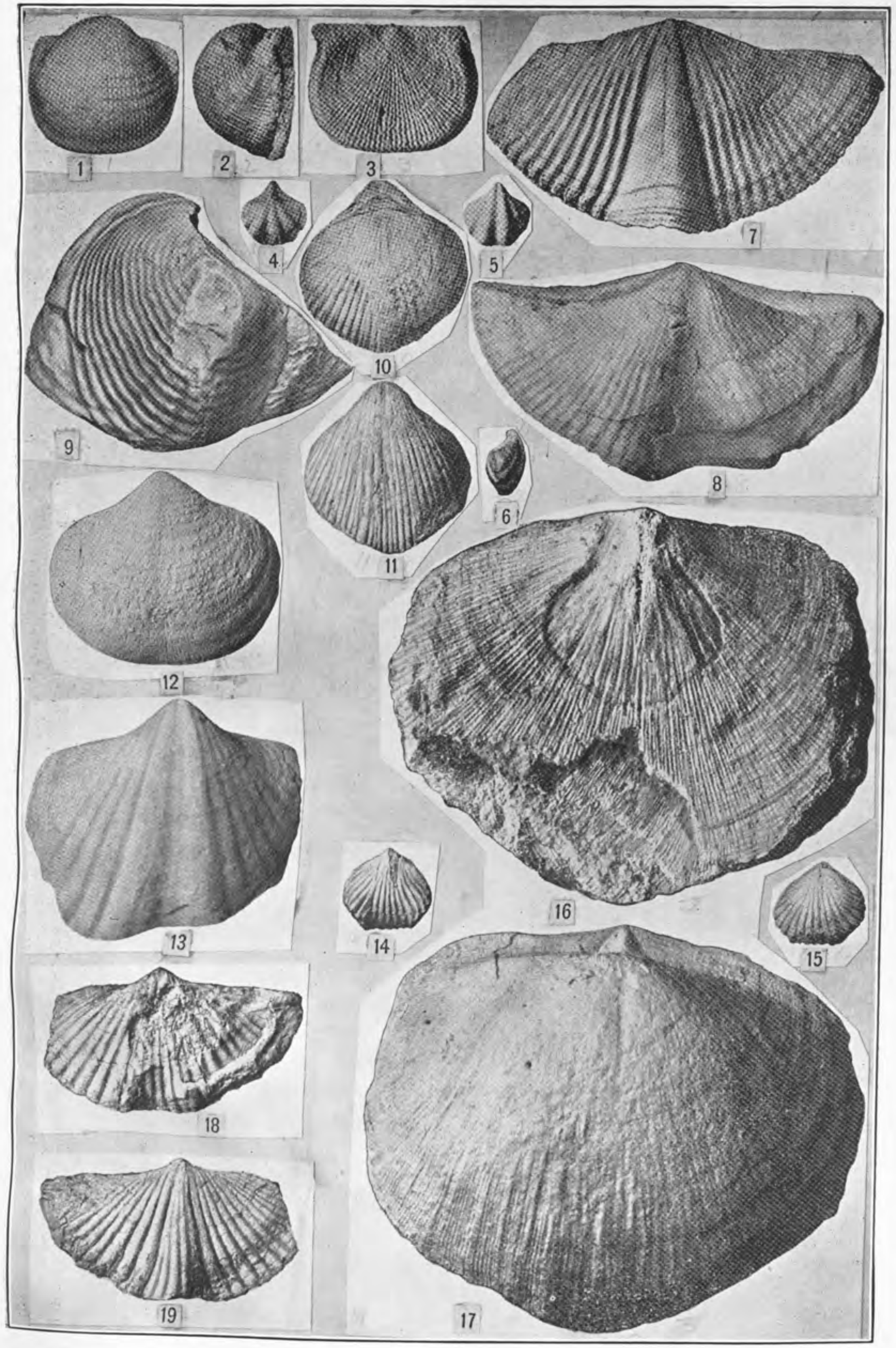


Plate 52.
Fossils of the Rosewood shale and Holtsclaw sandstone.
All after Weller.

WARSAW ("HARRODSBURG") LIMESTONE.

NAME AND DEFINITION.—The name Warsaw was taken from Warsaw, Indiana, and was originally applied by Hall* to a limestone bed which had been known previously as the Second Archimedes limestone. It is 18 feet thick. The application of the name was later extended downward to include about 23 feet of alternating shale and limestone, making 41 feet in all. Very recently it has been agreed to extend the formation downward to include at Warsaw 39 feet of shale and limestone containing geodes that have hitherto been included in the Keokuk. This makes the Warsaw at its type locality 80 feet thick. Thus amended, the Warsaw becomes the stratigraphic equivalent of the Harrodsburg and the latter name, being superfluous, is replaced in the Jefferson County region by Warsaw. In this region the Warsaw includes the siliceous limestone with chert layers and abundant geodes, and perhaps some shale, about 80 feet thick, limited below by the Holtsclaw sandstone and above by the coarsely crystalline gray limestone of easily recognizable different character, called the Spergen ("Salem" or "Bedford") limestone. The base of the Warsaw is marked at some exposures by a thin oolitic limestone 1 to 2 feet thick, or, where the oolitic layer is absent, by a bed of dark, green, glauconitic clay about 1 foot thick.

DISTRIBUTION.—The Warsaw is confined to the tops of the narrow ridges in the southwest marginal part of the county. It is not present on the Norton Hills nor on any of the knobs north of Pond Creek. A few patches are present on the ridge and spurs between Pond Creek and Crane Run. With the possible exception of one small area on a high knob on Moremens Hill east of Orel, all the ridges in this part of the county are capped by Warsaw beds, having no higher beds above them. The lower 20 feet or so of the Warsaw is usually well exposed and can be recognized by its geodes and yellow colored fragments. A good exposure of this part of the formation is in the road a few hundred yards southwest of the top of Mitchell Hill. The full section, 80 feet thick, is exposed in the bluff above the Louisville, Henderson and

*Hall, James, Am. Assoc. Adv., Sci., Proc., vol. X.

St. Louis Railroad 1½ miles east-northeast of West Point just east of the county line.

THICKNESS.—The thickness of the Warsaw in this region according to several good measurements, varied from 65 to 82 feet as shown in the plate of sections below. It is thinnest to the north.

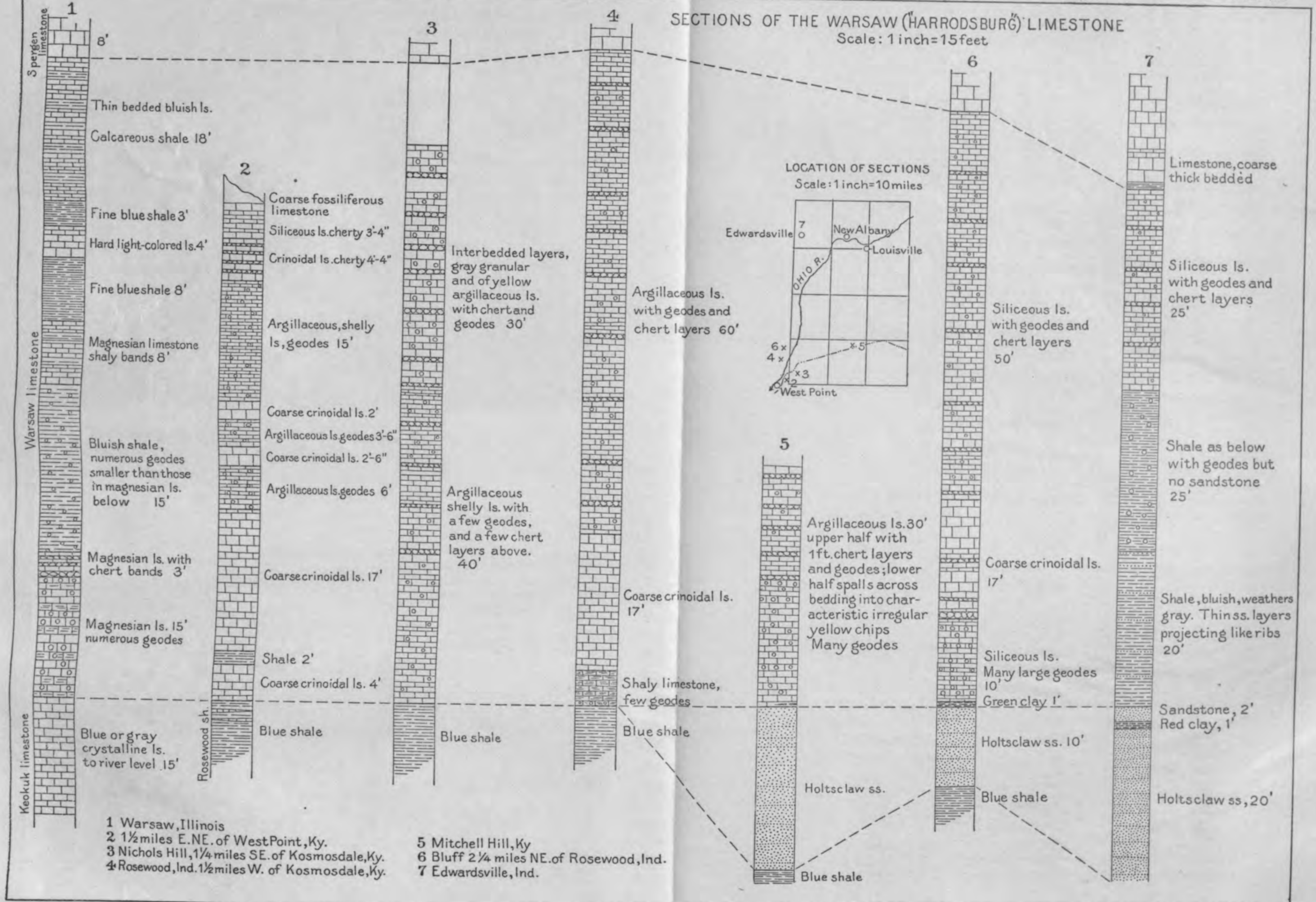
CHARACTER.—The Warsaw formation is composed of somewhat diverse elements, such as siliceous, geodiferous limestone, coarse crinoidal limestone, oolitic limestone, chert, shale, and clay, as shown by the sections of Plate 53. The relative position of some of the rock types enumerated above varies from place to place.

OOLITIC LIMESTONE AND CLAY.—Immediately overlying the Holtsclaw sandstone is either a layer of gray oolitic highly fossiliferous limestone 1 to 2 feet thick, or a dark-green clay 6 inches to 1 foot thick. This clay is very full of small grains of glauconite which gives it the green color. It has not been observed where the oolitic limestone is present and vice versa.

The oolites of the limestone compose a considerable proportion of its volume and are spherical or ovoidal in shape and commonly have a dark center or nucleus. They range from one-fourth to two-thirds mm. in their various diameters. The oolite was observed only on Mitchell and Jefferson Hills in the southwestern part of the county; the clay shows in the road west of Brooks, on the road southwest from the top of Mitchell Hill, and in a road on the bluff 2½ miles northeast of Rosewood, Indiana, which is opposite Kosmosdale.

The oolitic limestone outcrops in the road on the north side of Mitchell Hill and the dark clay in the road on the south side of the Hill about one-fourth of a mile distant.

SILICEOUS AND GEODIFEROUS LIMESTONE.—On Mitchell and Jefferson Hills and in that part of the county generally, the 15 feet of rock immediately overlying the oolitic limestone or dark clay is a siliceous limestone or possibly more properly a calcareous sandstone, since it seems to be composed more largely of very fine, angular, or subangular quartz grains than of calcium (lime) carbonate, although there is enough of the latter present to produce brisk effervescence on treatment with acid. This rock is bluish in the fresh condition, but weathers to a


SECTIONS OF THE WARSAW ("HARRODSBURG") LIMESTONE
Scale: 1 inch = 15 feet
1
Spergen limestone
8'
Thin bedded bluish ls.
Calcareous shale 18'
Fine blue shale 3'
Hard light-colored ls. 4'
Fine blue shale 8'
Magnesian limestone shaly bands 8'
Warsaw limestone
Bluish shale, numerous geodes smaller than those in magnesian ls. below 15'
Magnesian ls. with chert bands 3'
Magnesian ls. 15' numerous geodes
Keokuk limestone
Blue or gray crystalline ls. to river level 15'
2
Coarse fossiliferous limestone
Siliceous ls. cherty 3'-4"
Crinoidal ls. cherty 4'-4"
Argillaceous, shelly ls, geodes 15'
Coarse crinoidal ls. 2'
Argillaceous ls. geodes 3'-6"
Coarse crinoidal ls. 2'-6"
Argillaceous ls. geodes 6'
Coarse crinoidal ls. 17'
Shale 2'
Coarse crinoidal ls. 4'
Rosewood sh.
Blue shale
3
Interbedded layers, gray granular and of yellow argillaceous ls. with chert and geodes 30'
Argillaceous shelly ls. with a few geodes, and a few chert layers above. 40'
Blue shale
4
Argillaceous ls. with geodes and chert layers 60'
Coarse crinoidal ls. 17'
Shaly limestone, few geodes
Blue shale
LOCATION OF SECTIONS
Scale: 1 inch = 10 miles
Edwardsville
New Albany
Louisville
OHIO R.
West Point
5
Argillaceous ls. 30' upper half with 1 ft. chert layers and geodes; lower half spalls across bedding into characteristic irregular yellow chips
Many geodes
Holtsclaw ss.
Blue shale
6
Siliceous ls. with geodes and chert layers 50'
Coarse crinoidal ls. 17'
Siliceous ls. Many large geodes 10'
Green clay 1'
Holtsclaw ss. 10'
Blue shale
7
Limestone, coarse thick bedded
Siliceous ls. with geodes and chert layers 25'
Shale as below with geodes but no sandstone 25'
Shale, bluish, weathers gray. Thin ss. layers projecting like ribs 20'
Sandstone, 2'
Red clay, 1'
Holtsclaw ss, 20'
1 Warsaw, Illinois
2 1½ miles E.NE. of West Point, Ky.
3 Nichols Hill, 1¼ miles SE. of Kosmosdale, Ky.
4 Rosewood, Ind. 1½ miles W. of Kosmosdale, Ky.
5 Mitchell Hill, Ky
6 Bluff 2¼ miles NE. of Rosewood, Ind.
7 Edwardsville, Ind.

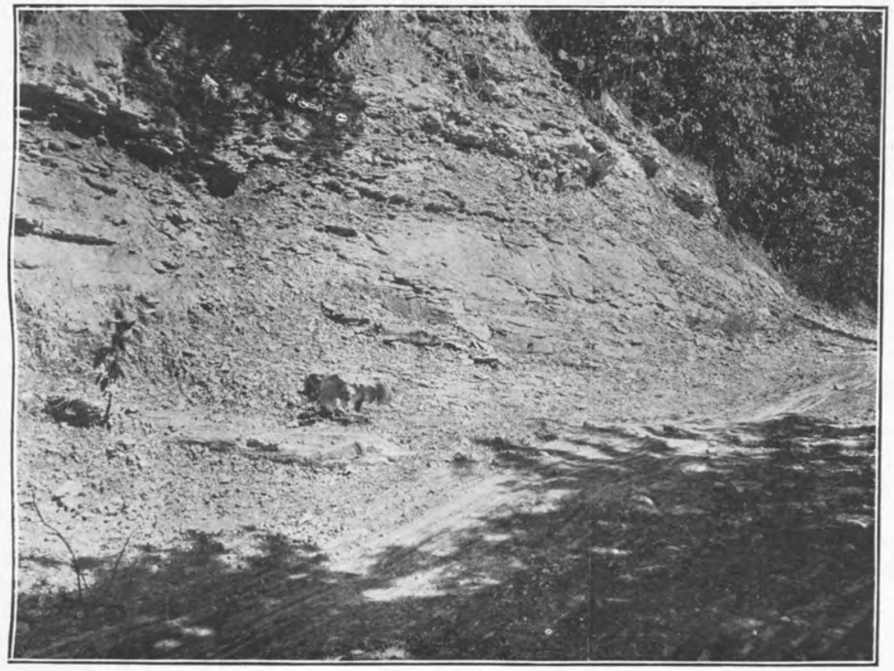


Plate 54.

The lower 15 to 20 feet of the Warsaw limestone. Road on the north side of Mitchell Hill about 70 feet below the summit. Looking south. Shows the characteristic chips due to spalling on weathering. The formation can easily be identified by these chips.

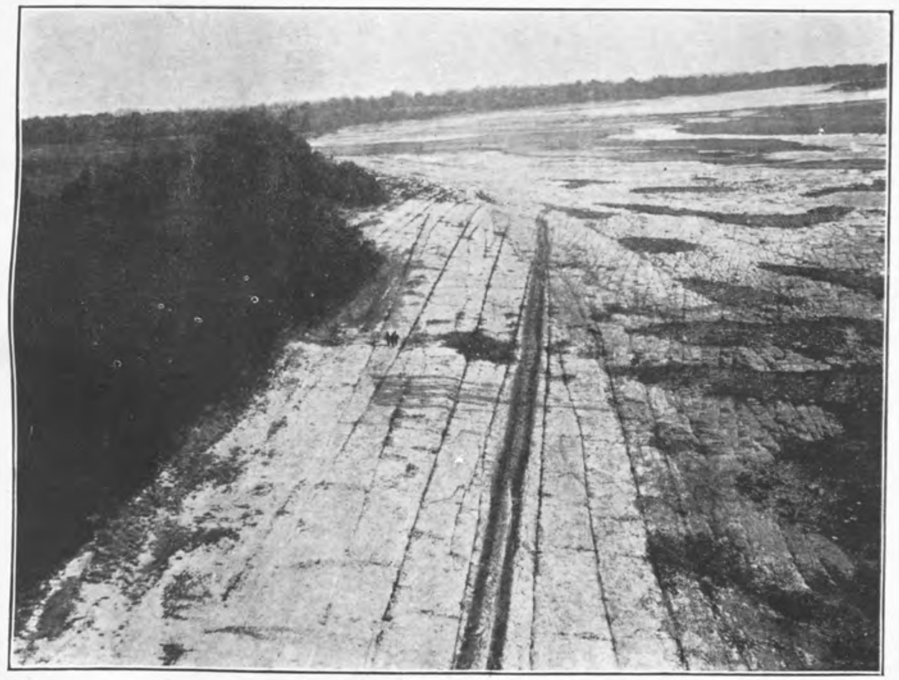


Plate 55.

New Albany shale showing jointing. Just above Kentucky and Indiana bridge. New Albany, Indiana. Looking east.

yellowish color. On weathering it splits up diagonally to the bedding into irregular, flattened fragments, most of which are smaller than the hand, and these everywhere strew the surface where rock of this type outcrops so that it is in all cases easy to locate the base of the Warsaw. The general appearance of this type of rock on a fresh shallow exposure is shown on Plate 54 and Plate 55.

While this phase of the Warsaw seems more prominently developed in the basal 15 feet in the southern part of Jefferson County, at other places it is more prominent in the upper part, as in Section No. 2 (Plate 53), 1½ miles east-northeast of West Point. In the section at Rosewood, Indiana, No. 4, and in that 2¼ miles northeast of Rosewood, No. 6, this phase makes up the whole upper three-fourths of the total section and in the latter section is also prominently developed in the basal 10 feet. At Edwardsville, Indiana, Section No. 7, the siliceous limestone phase occupies the upper 25 feet of the whole thickness. (See Plate 53.)

COARSE CRINOIDAL LIMESTONE.—In the Section No. 2 and the lower 23 feet in Section No. 4 at Rosewood, Indiana, 1½ miles west of Kosmosdale, the lower 20 feet, and in Section No. 6, 2¼ miles northeast of Rosewood, about 15 feet beginning 10 above the bottom, is coarse, medium thick bedded limestone, largely composed of crinoidal joints up to one-half inch in diameter. In some of the sections, especially Nos. 3 and 5, limestone of this character alternating with chert layers is common in the upper half of the Warsaw. (See Plate 53.)

CHERT.—At the localities represented by Sections Nos. 3 and 5, Plate 53, siliceous, dense, yellow chert layers with abundant sponge spicules come into the sections and are of more or less regular occurrence to the top. Most of the chert layers are dense, structureless and yellowish, with many white, needle-like sponge spicules of silica visible only with a glass on a freshly broken surface. Other chert layers are, however, plainly silicified crinoidal limestone, bowlders of which, at first glance, are easily mistaken for fine conglomerate because of the white, pebble-like appearance of the crinoidal joints.

SHALE AND SANDSTONE.—In the Edwardsville, Ind., section, No. 7, the lower 40 feet of the Warsaw is composed mostly of bluish, gray-weathering shale, in the

upper 20 feet of which are a few geodes and in the lower 20 feet are a number of sandstone bands 2 to 6 inches thick, which, being more resistant to weathering, project slightly from the enclosing shale. About $2\frac{1}{2}$ feet of bluish shale is present in the midst of the basal coarse crinoidal limestone in the Section No. 2, $1\frac{1}{2}$ miles east-northeast of West Point.

GEODES.—Geodes have frequently been mentioned. These are more or less regularly spherical or spheroidal bodies of quartz. They consist of an outer solid continuous shell enclosing a hollow space within, the surface of which is lined with quartz crystals. These bodies vary in size from that of a pea up to a diameter of 4 inches or even more in rare cases. They are enclosed in the solid rock, and are apparently more abundant in the siliceous limestone, from which they are liberated on the disintegration of the rock, so that they lie free upon the surface. They are especially plentiful in the beds of streams that head upon the slopes below the outcrop of the Warsaw. These bodies are practically confined to the Warsaw and serve to identify it. A very few very small geodes were noted in the Holtsclaw sandstone, but they do not vitiate the value of the geodes as a criterion for recognizing the Warsaw. As can be seen in the sections of Plate 53, the geodes extend throughout the Warsaw from top to bottom in this region. However, at Warsaw, Illinois, the type locality of the formation, they are, according to published sections, confined to the lower half, in which they are prominent.

FOSSILS.—The Warsaw is not very fossiliferous but a considerable number of forms were collected during the course of the field work which are listed below:

List of Fossils From the Warsaw Limestone.

Sponge spicules.

Corals.
- Cladochonus beecheri? Grabau.
- Palaeacis carinata. Girty.
- Triplophyllum sp.
- Zaphrentis carinata. Worthen.

Crinoids.
- Echinocrinus sp.
- Synbathocrinus aff. swallowi. Hall.

Bryozoa.
- Archimedes negligens. Ulrich.
- Batostomella several species.
- Cystodictya sp.
- Cystodictya lineata. Ulrich.
- Fenestella several species.
- Fistulipora elegans?
- Fistulipora sp.
- Glyptopora sagenella. Prout.
- Hemitrypa sp.
- Lioclema gracillinum. Ulrich
- Lioclema punctatum. Hall.
- Meekopora sp.
- Phractopora trifolia. Rominger.
- Pinnatopora aff. vinei. Ulrich.
- Polypora biseriata. Ulrich.
- Polypora sp.
- Rhombopora sp.
- Stenopora americana? Ulrich.
- Stenopora? sp.
- Streblotrypa major. Ulrich.
- Streblotrypa sp.
- Worthenopora spinosa. Ulrich.

Brachiopods.
- Athyris densa. Hall.
- Avonia? n. sp.
- Brachythyris gurleyi? Weller.
- Brachythyris subcardiformis. Hall.

Camarotoechia? sp.
Dielasma sp.
Eumetria verneuilliana. Hall.
Orthotetes kaskaskiensis. McChesney.
Orthotetes keokuk? Hall.
Productus keokuk? Hall.
Productus magnus. Meek and Worthen.
Productus ovatus. Hall.
Productus setiger? Hall.
Productus semireticulatus. Martin.
Productus n. sp.
Pseudosyrinx keokuk? Weller.
Pustula alternata. Norwood and Pratten.
Pustula biseriata? Hall.
Pustula aff. indianensis. Hall.
Pustula punctata. Martin.
Reticularia setigera. Hall.
Reticularia sp.
Rhipidomella dubia. Hall.
Rhynchopora beecheri? Greger.
Spirifer bifurcatus. Hall.
Spirifer lateralis. Hall.
Spirifer tenuicostatus. Hall.
Spirifer washingtonensis. Weller.
Spiriferella neglecta. Hall.
Spiriferina aff. spinosa. Norwood and Pratten.
Spiriferina sp.
Syringothyris solidirostris. Weller.

Pelecypods.
Aviculipecten amplus. Meek and Worthen.
Aviculipecten sp.
Leptodesma n. sp.
Myalina sanctiludovici. Worthen.
Schizodus sp.

Gastropods.
Bellerophon sp.
Bembexia n. sp.
Euconispira sp.
Euomphalus quadrivolvis. Hall.
Euomphalus sp.
Fleurotomaria sp.

A few representative species of the Warsaw limestone are illustrated on Plate 56.

AGE AND CORRELATION.—On the basis of lithic similarity and stratigraphic position, the formation here under discussion is correlated with the Warsaw limestone typically exposed at Warsaw, Illinois. The Warsaw at that place, including the lower 40 feet of magnesian limestone with geodes, formerly included in the Keokuk, but now by the best authorities placed in the Warsaw, succeeds the Keokuk as in Jefferson County. Certain of the fossils listed above confirm this correlation. Thus *Brachythyris subcardiiformis*, *Spirifer lateralis*, *Spirifer sp.*, *Spirifer tenuicostatus* seem not to occur below the Warsaw, at Warsaw, Illinois, although they occur in the Spergen limestone above the Warsaw as shown in the list. *Productus magnus* and *Aviculipecten amplus*, two of the most characteristic forms in the Warsaw fauna of this region, are likewise present in beds in Monroe County, Illinois, which Weller identifies with the typical Warsaw. All lines of evidence converge then in establishing the Warsaw age of the beds here under discussion and justify the substitution of the name Warsaw for "Harrodsburg" hitherto in use.

SPERGEN ("SALEM" OR "BEDFORD") LIMESTONE.

NAME AND DEFINITION.—There has been considerable controversy over the name of the limestone here under description. In Indiana it has been called Bedford rock, Bedford oolitic limestone, and later (1901) Salem limestone. The name definitely adopted by the U. S. Geological Survey in 1904, after prior usage by various early writers,* and after consideration of the widely established use of the terms Spergen Hill fauna and Spergen fauna, is used in this report. The original form, Spergen Hill beds, taken from Spergen Hill, Washington County, Indiana, about 20 miles nearly north of Louisville, is, however, modified to Spergen limestone.

In this region the Spergen is defined as including the 20 feet mainly of thick-bedded, coarse, gray limestone overlying the geodiferous Warsaw formation.

DISTRIBUTION.—The Spergen is not positively known from observation to be present in Jefferson County, but it is probably present on a high knob on one of the south-pointing spurs of Moremens Hill near the west end of the ridge between Crane Run and Pond Creek in the southwest part of the county. This knob is high enough to carry the Spergen after allowing for the thickness of the lower formations. This small area is not shown on the map. The Spergen is present on Pendleton Hill south of the county and 1½ miles southeast of Medora and also on Nichols Hill, 1¼ miles southeast of Kosmosdale. It is also present along the west bluff of Ohio River in Indiana, where it outcrops near the brow of the bluff. Possibly there are other small patches of the formation on some of the ridges or knobs along the south boundary of Jefferson County, but no such occurrences were established by observation.

THICKNESS.—The thickness of the Spergen does not appear to exceed 20 feet in this region and it is reported as little as 5 feet in places in the adjoining parts of Indiana. At Edwardsville, Indiana, where it is best exposed in a quarry it is 25-30 feet thick.

*S. S. Lyon (St. Louis Acad. Sci., Trans., vol. 1, p. 619, 1860); C. E. Siebenthal (Indiana Dept. Geol. and Nat. Res., 21st Ann. Rept., p. 298, 1897); S. Weller (Jour. Geol., vol. 6, p. 313, 1898); and H. S. Williams (Arkansas Geol. Sur., vol. 5, p. 348, 1900).

CHARACTER.—The Spergen in this region is a coarse-grained, thick-bedded gray limestone. It shows very little of the oolitic character that it has farther north in Indiana, where it is so extensively quarried and sold under the name, Bedford oolitic limestone. A specimen collected on Nichols Hill contains numerous grains of a green mineral, believed to be glauconite, and an occasional grain of pyrite.

FOSSILS.—The Spergen is moderately fossiliferous, brachiopods and bryozoa being the most abundant. A list of the forms collected in the neighborhood of Jefferson County is given below:

List of Fossils From the Spergen Limestone.

Foraminifera.
- Endothyra baileyi. Hall.

Corals.
- Cladochonus beecheri. Grabau.
- Cladochonus sp.
- Triplophyllum sp.

Crinoids.
- Echinocrinus sp.
- Pentremites conoideus. Hall.
- Pentremites? sp.

Vermes (Worms.)
- Spirorbis annulata. Hall.
- Spirorbis sp.

Bryozoa.
- Batostomella sp.
- Cystodictya lineata. Ulrich.
- Cystodictya pustulosa. Ulrich.
- Dichotrypa? sp.
- Fenestella several species.
- Fenestella tenax? Ulrich.
- Fistulipora sp.
- Hemitrypa hemitrypa. Prout.
- Hemitrypa var. nodulosa. Ulrich.
- Hemitrypa sp.
- Lioclema sp.
- Meekopora? sp.
- Polypora biseriata? Ulrich.
- Polypora simulatrix? Ulrich.

Polypora sp.
Ptilopora valida. Ulrich.
Rhombopora? sp.
Stenopora sp.
Worthenopora spatulata. Ulrich.
Worthenopora spinosa. Ulrich.

Brachiopods.
Brachythyris subcardiiformis. Hall.
Camarotoechia? sp.
Cliothyridina hirsuta. Hall.
Cliothyridina parvirostus. Meek and Worthen.
Cranaena sulcata? Weller.
Crania sp.
Composita trinuclea. Hall.
Dielasma sp.
Eumetria verneuiliana. Hall.
Orthotetes aff. kaskaskiensis. McChesney.
Productus aff. gallatinensis. Girty.
Productus keokuk. Hall.
Productus ovatus. Hall.
Productus setiger. Hall.
Productus n. sp.
Pustula alternata. Norwood and Pratten.
Reticularia setigera. Hall.
Rhynchopora sp.
Schuchertella minuta? Cumings.
Spirifer bifurcatus. Hall.
Spirifer lateralis. Hall.
Spirifer tenuicostatus. Hall.
Spirifer washingtonensis. Weller.
Spiriferella neglecta. Hall.
Tetracamera arctirostrata? Swallow.

Pelecypods.
Allerisma maxvillense? Whitfield.
Conocardium aff. catastomum. Hall.
Conocardium sp.
Cypricardella subelliptica? Hall.
Cypricardinia indianensis? Hall.
Cypricardinia sp.
Deltopecten sp.
Leptodesma spergensis. Whitfield.
Leptodesma sp.
Myalina sp.
Pteronites? sp.
Worthenia? sp.

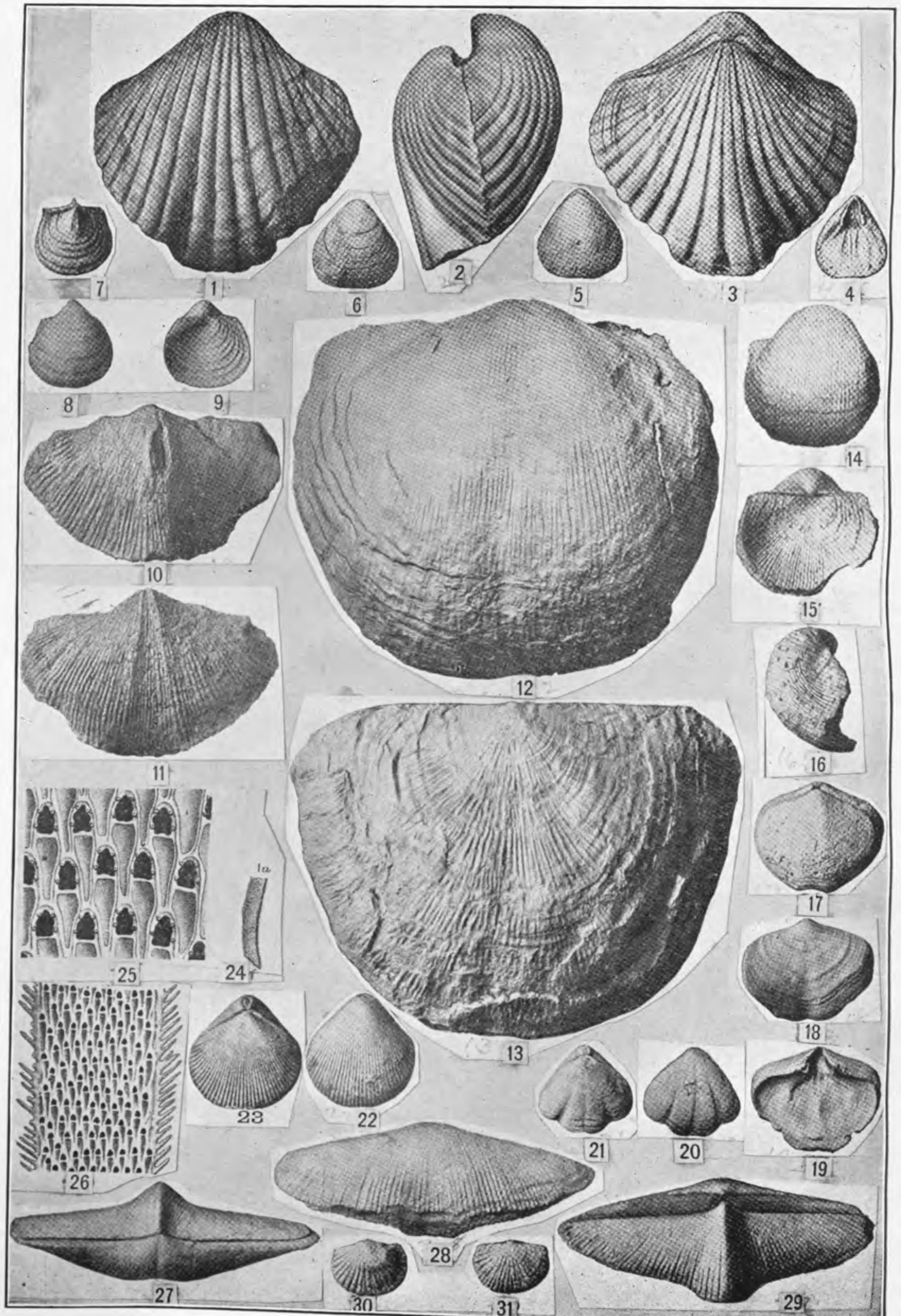


Plate 56.
Fossils of the Warsaw formation and Spergen limestone. All after Weller except Nos. 24-26.

Gastropods.
- Bembexia n. sp.
- Euomphalus planispira. Hall.
- Holopea? sp.
- Meekospira? sp.
- Murchisonia sp.
- Platyceras sp.

Cephalopods.
- Orthoceras sp.

Ostracods.
- Cytherella? sp.
- Kirkbya reflexa?
- Paraparchites carbonarius? Hall.

Trilobites.
- Griffithides sp.

A few of the species listed above are shown on Plate 56.

Fossils of the Warsaw Formation and Spergen Limestone. All After Weller Except Nos. 24-26.

Plate 56.

1-3 Brachythyris subcardiformis. Hall. 1, pedicle; 2, profile; and 3, brachial view. Warsaw and Spergen.

4-6 Rhipidomella dubia. Hall. 4, interior of pedicle valve; 5, brachial; 6, pedicle valve. Wasaw and Spergen. Common.

7-9 Echinoconchus (Pustula) biseriatus. Hall. 7, interior of a brachial valve; 8, pedicle; 9, brachial valve.

10-11 Spirifer tenuicostatus. Hall. 10, pedicle; 11, brachial valve. Rosewood shale to Warsaw formation.

12-13 Productus magnus. Meek and, Worthen. 12, pedicle; 13 brachial valve. Warsaw formation only. Characteristic form.

14-16 Productus altonensis. Norwood and Pratten. 14, pedicle; 15, brachial; and 16, profile view. Spergen limestone. Listed as productus aff. gallatinensis.

17-19 Athyris densa. Hall. 17, brachial; 18, pedicle valve; 19, interior of pedicle valve. Warsaw formation.

20-21 Composite trinuclea pedicle and brachial valves. Spergen limestone.

22-23 Eumetria verneuiliana. Hall. Pedicle and brachial valves. Holtsclaw sandstone to Spergen limestone.

24-26 Worthenopora spinosa. Ulrich. Common and characteristic bryozoan of the Warsaw formation and Spergen limestone. 24, specimen natural size; 25 and 26, enlarged views. 26 shows the characteristic spines.

27-29 Spirifer lateralis. Hall. 27, cardinal; 28, pedicle; 29, brachial view. Warsaw formation and Spergen limestone.

30-31 Streplorhynchus (Orthotetes) minutum. Cummings. Brachial and pedicle valves. Salem limestone.

AGE AND CORRELATION.—As in the case of the Warsaw the limestone here under discussion is by its lithic character and stratigraphic position correlatable with the Spergen. Furthermore its stratigraphic continuity with the Spergen has been established by tracing the formation from that part of Indiana lying across the Ohio from Jefferson County to the type locality, Spergen Hill, some 20 miles north of Louisville.

The fossil evidence is conflicting. A number of forms in the above lists are characteristic members of the Spergen fauna as developed at the famous locality, Spergen Hill. Among these are *Endothyra baileyi, Pentremites conoideus, Spirorbis annulata, Cliothyridina hirsuta, Productus aff. gallatinensis, Composita trinuclea, Schuchertella minuta?, Conocardium aff. catastomum, Cypricardella (Microdon) subelliptica, Cypricardinia indianensis?* and *Leptodesma (Pteronites?) spergensis, Griffithides sp.* Some of these forms occur in the bottom of the limestone, others, as *Endothyra baileyi,* is identified only from the top. While this fauna is very small as compared with the whole typical diminutive Spergen fauna, it is still strong evidence of the Spergen age of the beds containing it, and this evidence, combined with that furnished by the lithic character and stratigraphic relations of the limestone, is quite conclusive.

There is obviously a close relation between the Warsaw fauna and the Spergen fauna as a whole, including forms not present in the restricted fauna of Spergen Hill. This is so strong that the Warsaw and Spergen were correlated by the early writers, among which was Hall.

QUATERNARY SYSTEM.

The Quarternary system includes alluvial and gravel deposits along Ohio River, of Pleistocene (glacial) age, and alluvium deposited along the margins of the streams, of recent age.

PLEISTOCENE SERIES.

GLACIAL OUTWASH DEPOSITS.

The glacial outwash deposits are composed of alluvium, clay, and gravel now forming the terrace one-half mile to 5 miles wide bordering the eastward side of Ohio River along its entire length in Jefferson County. This deposit has now a maximum thickness of about 100 feet and originally, before any of it was removed by erosion, may have been thicker in places. At the base of the Pleistocene deposit is a layer of moderately coarse gravel, the pebbles being rounded and predominantly 1 to 4 inches in diameter. In places the gravel appears to be only about 5 feet thick, in others seemingly of greater thickness. The pebbles are largely of crystalline rocks, granite, quartzite, etc. These pebbles are known to have been derived from Canadian sources, since no granite or quartzite outcrops in the area covered by the glaciers in the nearer regions. The gravel is exposed just overlying the New Albany shale in the west end of the Louisville canal, in the excavation for the open sewer at Broadway and Beargrass Creek, Louisville, and also in a gravel pit some distance southwest of the last point. Gravel is not confined to the basal part of the Pleistocene, however, although the coarsest has not been seen at a higher horizon. Fine quartz gravel is fairly plentiful in the alluvium near Kosmosdale, 100 feet above the bottom of the outwash deposits.

The alluvium is composed of river silt, sand, and clay variously mixed and distributed. In the Louisville canal a considerable thickness of dark clay overlies the gravel bed, and, higher in the alluvial deposit, sufficient clay is present in places to make the material suitable for the manufacture of a good grade of brick. At other points as near the electric railroad station, at the upper Country

Club, and just north of Harrods Creek, sand suitable for mortar, etc., is present in gravel or as bands alternating with earthy alluvium. This Pleistocene outwash deposit now forms a terrace between the river and the bluffs northeast of Louisville and between the river and the Knobs southwest of Louisville. Louisville is mostly located upon it.

However, not all of the material of this terrace was deposited in Pleistocene time, for a considerable material has been contributed to its surface in more recent times by the wash from the bluffs and knobs. Nevertheless the great bulk of the deposit is of glacial age. It was washed out from the ice on melting and, surcharging the rivers by its great quantity, was deposited in the pre-glacial river valleys, filling them to the present height above their bottoms or even to a greater height, for there has been some removal of material from the top since deposition. The origin of the terrace deposits is further discussed in the section on Historical Geology of this report.

LOESS.—On the authority of Mr. E. W. Shaw, geologist of the U. S. Geological Survey, who is making extensive studies of Pleistocene deposits in the Mississippi Valley, a small area of typical loess occurs on the low alluvial ridge extending from Prospect southward for a mile. Loess is a very fine-grained, compact earth or loam or very fine sand, and is believed to be largely if not wholly a wind-blown deposit of fine rock dust. It has not been recognized elsewhere in the county and its identification at the locality mentioned may not be beyond doubt.

AGE AND CORRELATION.—The Pleistocene deposits described above as filling the valley of Ohio River to a depth of 100 feet in this county are believed to have been deposited in the Illinoian and Wisconsin stages of glaciation, since these two stages seem to be the only ones in which the ice sheets approached near enough to this region to supply any notable quantity of detritus such as enters into the composition of the terrace deposits.

RECENT DEPOSITS.

ALLUVIUM.—The alluvium is the sheet of silt and other fine sediment deposited along streams when overflowing the bordering low ground in recent times. Such deposits are narrow along most of the streams but cover larger areas along Floyds Fork, where they surface the fertile bottom lands immediately bordering the stream. The thickness of the alluvium probably does not much exceed 10 feet, for nearly all the streams are flowing on rock bottom, generally not more than 10 or 15 feet below the flat alluvial lands, for long stretches of their beds. The alluvium along such streams as flow for part at least of their length over the Pleistocene deposits has not been mapped separately from the latter as, owing to the close similarity of the two, they can not be readily distinguished, and besides there is no practical advantage in making the separation.

CHAPTER 5.

GEOLOGIC STRUCTURE.

Definition.—By geologic structure as used here is meant the larger features of the strata considered as extensive sheets of rock, such as the attitude of the strata, whether horizontal or inclined, lying in a series of waves or folds, or fractured and displaced along breaks (faulted.)

As already explained sedimentary rocks deposited in water bodies such as existed in the Jefferson County region were laid down as extensive sheets or layers called strata in a nearly horizontal attitude. But at the present time they are not horizontal, but more or less inclined. In other words they are deformed from their original attitude. They have been bodily uplifted in some localities more than in others so as to produce a sort of broad dome and depression structure, or they have been broadly crumpled by sidewise pressure which produced a series of folds, some of which extend for long distances as continuous features, such as the Springdale anticline;* others are minor puckerings only a few miles in extent, such as the short structural ridges east of Floyds Fork. Such features are in general called folds. The upward bending folds are called anticlines, and the downward bending ones synclines. The line connecting the highest points on the surface of any stratum along the crest of the anticline or the lowest points along the bottom of the syncline is called the axis.

Breaks across strata with relative displacement so that strata on opposite sides of the break no longer match are called faults. No faults have been detected in Jefferson County, but they are common features in Western Kentucky. The dip of the strata is their angle of declination from a horizontal plane measured in the direction in which it is greatest. The strike of strata is the

*See county map.

direction of a horizontal line upon the surface of a given inclined stratum. It is always in a direction at right angles to the direction of dip.

METHOD OF REPRESENTING STRUCTURE.—There are two methods of representing structure, the method of structure sections and the method of structure contours.

In the structure section method the lay of the strata is represented as it would appear from the edges of the strata exposed in a deep trench, usually supposed to be in the direction of the dip. This method is highly instructive, but has the disadvantage of exhibiting the structure for a narrow strip only, immediately adjacent to the line of section. The structure of the county is thus shown by two sections constructed along the lines AA and BB drawn across the geologic map.

In the structure contour method the lay of the strata is delineated by lines drawn at equal vertical intervals on the top or bottom of a given stratum called the reference bed. Each structure contour line is designed to pass through all points of the reference bed at the same height above sea level, which is the ultimate datum plane. Any such line would mark the shore line if the actual land surface coincided with the reference surface and the country were lowered so as to be overflowed by the sea at the level of the given line. It is obvious that the steeper the dip of the strata the closer these contour lines will be together, and vice versa. Thus it is possible to represent the degree and direction of the slope of the strata in all parts of the area in as great detail as they can be determined. The method is the same as the contour method of representing the shape and relief of the land surface.

In Jefferson County the reference surface chosen is the top of the Waldron shale. In determining the altitude above sea level of points on this surface there are three cases: 1st, the surface outcrops and the altitude can be determined directly; 2nd, the surface is underground and points can be determined directly in a few cases by well borings, but mainly they must be determined by calculation from the known thickness of strata intervening between points on the land surface and the top of the reference surface; 3rd, the reference surface has been eroded away and its original elevation above sea level at any point, which is now also above the present

land surface, is calculated from the thickness of strata known to have originally intervened at the given point between the geologic horizon of the present surface and the reference surface. Thus for example, under the 2nd case, let it be desired to compute the elevation above sea of a point on the top of the Waldron shale beneath the top of Kenwood Hill. On the topographic map the elevation above sea level of the top of the knob is shown to be 740 feet. By adding the thicknesses of the different strata down to the top of the Waldron, viz.:

	Feet
Kenwood sandstone	30
New Providence shale	160*
New Albany shale	100*
Devonian limestone	20*
Louisville limestone	80*
Waldron shale top below top of Kenwood Hill	390

Since the top of Kenwood Hill is 740 feet above sea level, by subtraction of 390 from 740, 350 feet is obtained for the elevation of the top of the Waldron and the 350-foot structure contour passes through that point as shown on the geologic map.

Under case No. 3 let it be desired to calculate the original height of the reference surface, before it was eroded away, above Fisherville. The bottom of the Waynesville formation is about 590 feet above sea level at Fisherville. The thickness of the strata intervening between the bottom of the Waynesville and the top of the Waldron shale is as follows:

	Feet
Waldron shale	10
Laurel dolomite	40
Osgood formation	30
Saluda limestone	40
Liberty formation	50
Waynesville limestone	40
Total thickness between the bottom of the Waynesville and the top of the Waldron	210

To obtain the original height of the top of the Waldron at the point selected, 210 feet, the thickness of the intervening eroded beds, is added to 590 feet, the height

*More or less.

of the bottom of the Waynesville, and the sum is 800 feet, the required height. Accordingly the 800 foot structure contour is drawn through Fisherville. By these processes as many points as desired can be determined upon the reference surface. As an actual fact the points on the reference surface are calculated from any horizon that is mostly accurately determined at any point as the top or bottom of the Saluda, bottom of the Liberty, top of the Louisville limestone, top or bottom of the New Albany shale, etc.

The contour interval used in this report is 10 feet; for example the 500-foot contour passes through points on the top of the Waldron calculated to be 500 feet above sea level, the 490-foot contour passes through points 490 feet above sea level, and the 510-foot contour passes through points 510 feet above sea level.

ACCURACY OF STRUCTURE CONTOURS.—There are several obvious sources of error in the calculations above described: 1st, the surface elevation may be inaccurate; 2nd, the elevation of the geologic horizon upon which a calculation is based may not be precisely determined, and 3rd, the thicknesses of formations vary from place to place, although their thicknesses seem to be quite uniform in this region, especially the total thickness of a number of formations, since the variation of the thicknesses of the formations at different points are likely to be compensatory, if one is thinner another may be thicker, etc.

Contours generally, whether topographic or geologic, are supposed to be accurate within the limit of the contour interval, that is to say, that the height of the top of the Waldron shale as represented by the contours should not vary from the actual height by more than 10 feet. However, in those parts of the county where the position of the contours is determined by calculation, as in the western part where the shale is at considerable depth, or in the eastern part where the Waldron has been removed by erosion and the horizon of its top is above the existing land surface, it is improbable that the structure contours are within the ideal limits of accuracy. Nevertheless they present a substantially correct picture of the shape and relative altitude above sea level of any geologic horizon.

DETAILED DESCRIPTION OF STRUCTURE.

The main structural feature of the county is the general westward or slightly northwestward dip from which it results that strata lie much nearer sea level in the western than in the eastern part of the county. The Waldron shale, the horizon of which is 900 feet above sea level on the east side of the county is 150 feet below sea level at the southwestern extremity of the county, making a total descent of 1,050 feet in crossing the county from east to west, an average dip of about 44 feet per mile and an average angle of dip of about ½ of 1 degree.

The westward slope of the rocks is neither continuous nor uniform, however. On the east side of the county, east of Floyds Fork, the strata are affected by a number of transverse wrinkles or small anticlines and synclines whose axes strike east and west and pitch westward and die out a mile or two west of Floyds Fork. Still farther westward the strata through a belt about 8 miles wide, slope with considerable uniformity westward, but there is a decided increase in the steepness at Jeffersontown and along the east base of the Norton Hills, plainly indicated by the crowding of the structure contours in those localities.

LYNDON SYNCLINE.—The westward descent of the strata continues to an axis which passes through Lyndon, west of which the strata rise, forming thus a structural trough known as a syncline and named the Lyndon syncline. This syncline is most pronounced from Lyndon southwestward in which direction the axis slopes or pitches and the syncline broadens. Eastward from Lyndon the axis traverses in a general eastward direction, the belt of uniformly dipping strata already described, and probably disappears near the east boundary of the county. East of Lyndon this axis really becomes a subordinate feature of the broad westward sloping belt.

Likewise a broad southward pitching anticline whose axis lies nearly 1 mile east of the railroad and terminates southward to the east of Forest, is also a minor structure superimposed upon the westward sloping belt. This structure may develop into a pronounced anticline east of Jefferson County.

SPRINGDALE ANTICLINE.—From the axis of the Lyndon syncline the strata rise westward to the crest of an arch which is named the Springdale anticline from Springdale near which the axis passed. This axis is offset to the east of Louisville; but the main structure is practically continuous from Pond Creek northeastward to where it dies out on the general northwestern slope of the strata east of Springdale. South of Pond Creek the anticlinal structure is not recognizable. The steepest southeast dip on this anticline is in the vicinity of Kenwood Hill.

Along the south margin of the county the strata are affected by minor deformations, the most notable of which are the dome and depression on the hills 1 to 2 miles south of Fairdale.

From the axis of the Springdale anticline the strata resume their westward or northwestward dip which persists to Ohio River. In the narrow southwest extension of the county the direction of dip is southwest while in the northeast part it is northwest. The dip beneath the broad tract of alluvial deposit southwest of Louisville is less well determined than elsewhere, and being thus somewhat doubtful the structure is represented by broken instead of continuous lines. The general elevation of the strata was, however, checked at a number of points on the Indiana bluffs west of the river and along the river and canal at Louisville so that the structure as represented by the contours is probably nearly correct.

It is to be stated, however, that the dip probably is not as uniform as represented, as the facts presented below will prove. Beginning at the Kentucky and Indiana bridge at New Albany, the beds rise eastward 6 feet in the first 500 feet, lie nearly flat in the next 1,250 feet and then rise 4 feet in the next 1,250 feet, so that the dip is only 10 feet in the total distance of 3,000 feet. Such details can be made out, however, only under very exceptional conditions of exposure.

JOINTING.—Besides the larger structural features just described, the rocks are affected by other structures, of which jointing is one of the most prominent. A good example of this is displayed by the New Albany shale just above the Kentucky and Indiana bridge at New Albany, Ind., as shown in Plate 55.

CHAPTER 6.

GEOLOGIC HISTORY.

INTRODUCTORY STATEMENT.—The geologic history of a region may be defined as an account of the events during known geologic time in that region, as deduced from the records contained in the rocks accessible to observation. A part of the geologic history of Jefferson County has been given in brief in the introduction to this report, in connection with the general history of the Appalachian Province. The present section will treat the geologic history from the time of deposition of the oldest exposed rocks in the county until the present.

Just as human history is divided into periods, epochs, etc., so is the history of the earth divided. In human history the periods and epochs are set off from each other by great changes affecting the destinies of nations, so the periods and epochs of geologic history are founded upon greater or smaller changes in conditions and events affecting large parts of the earth.

The divisions and subdivisions of geologic time and of the strata composing the crust of the earth so far as concerns this region have already been given. As the oldest exposed rocks of the county, up to very recent times, have been regarded and generally are so regarded still, as having been deposited in Ordovician time, the beginning of this history is set in the latter part of the Ordovician period.

In the part of the Ordovician period here recorded, the region was probably nearly continuously submerged, and received in the main calcareous sediment. Life flourished at times and at other times the seas in this region were rather sparsely populated.

ORDOVICIAN* PERIOD.

ARNHEIM EPOCH.

Somewhat remotely preceding the Arnheim epoch, it is inferred from the facts open to observation in the Cincinnati region and from the new facts revealed by deep well borings, that the Jefferson County region, like the larger region of which it is a part, was continuously submerged by sea water in which first several hundred feet of limestone was deposited and later several hundred feet of limestone and shale. In the seas lived a great many forms of animals which were the progenitors of those whose remains were buried in the exposed rocks of the region. The historic events recorded below had then their beginnings in earlier times, the records of which in this region are not now accessible to observation.

Immediately preceding the deposition of the Arnheim formation an extensive area of land is believed to have existed west of the Cincinnati region including Jefferson County. This belief is based upon the fact that the uppermost beds beneath the Arnheim formation at Cincinnati, the Mount Auburn and Corryville beds of Nickles, are absent at points nearer Jefferson County as at Madison, Indiana, and Sulphur, Kentucky, where the Arnheim rests upon Nickles's Bellevue beds, which at Cincinnati immediately underlie his Corryville beds. Hence, as explained previously, there is a stratigraphic gap or hiatus between the Arnheim formation, and the beds upon which it rests implying an intervening period of dry land. Subsidence beneath the sea, probably at a slow rate, ensued and in the water as it slowly crept over the old land the Arnheim sediment, derived from surrounding and perhaps distant limestone areas, was deposited. The shallow conditions and agitated water are indicated by the cross bedding and giant ripple marks (see Plates 4 and 6), by low beach marks made by swirling waves and by the accumulation in some thin layers of myriads of fossils, such as the large round brachiopod *Platystrophia,* which were pretty certainly washed together by waves and currents on the low shores or shallow sea bottoms.

*The age of the rocks here classed as Ordovician is a question in debate at present. The question is whether they are Ordovician or Silurian. By the use of the above heading the writer does not wish to be understood as accepting their Ordovician age.

The alternation of lumpy, calcareous shale and blue coarsely crystalline limestone seems to indicate times of muddy sediment from surrounding areas of limestone lands alternating with times without sediment from land, so that layers up to several feet in thickness of comparatively pure limestone had time to form in clear water. The clear, shallow water was the congenial habitat of innumerable animal forms whose remains are now so abundant in the limestone layers and which excite in the geologist the same interest that the human remains exhumed from some buried city in Egypt arouse in the archaeologist.

WAYNESVILLE EPOCH.

The apparently rapid variation of conditions characterizing the Arnheim epoch were succeeded at the beginning of the Waynesville by more stable conditions of sedimentation as a result of which rocks of more uniform character were deposited. The sea was evidently charged with abundant carbonate of lime and a considerable content of fine, argillaceous matter in suspension which settled together on the sea bottom to form the argillaceous limestone of the formation. At the beginning it seems that there must have been an approach to clear, shallow water conditions for a time, permitting the abundant growth of the coral *Columnaria,* which overspread at least the part of the county in which the Waynesville outcrops, and built up a thin reef. The limestone accumulation with *Columnaria* marking the advent of Waynesville time was succeeded by a period of predominantly argillaceous deposition forming the 10-foot greenish mottled calcareous shale bed overlying the *Columnaria* zone. On this muddy bottom flourished the bryozoan, *Cyphotrypa clarksvillensis,* the small, globular bodies of which are so abundant in the shale in places. After this shale deposition, the deposition of thick, argillaceous limestone layers prevailed to near the close of the Waynesville epoch, when more distinctly argillaceous matter was again present in the sea and layers of shale somewhat more fossiliferous than the limestone were laid down. In

Waynesville time, therefore, it appears that this part of Kentucky was covered by a shallow sea and was distant from land, so that only the finest sediment was carried out to it; or, if not distant, the land must have been of such low relief as to yield only very fine sediment.

In other parts of the Appalachian Province, however, conditions were different. Even at so near a point as Madison, Indiana, the Waynesville is very different from what it is in this region, being thin blue crystalline limestone in shale much like the Arnheim and Liberty formations in Jefferson County, and still farther northeast in Ohio it is predominantly shale.

The life conditions were much less favorable in Waynesville time than in the preceding Arnheim or succeeding Liberty epochs. In other places, however, living beings flourished abundantly in the epoch, and the distribution of animals was evidently controlled by conditions more or less local.

LIBERTY EPOCH.

In the Liberty epoch in this region there was a return to conditions similar to those prevailing in the Arnheim as is shown by the alternating deposition of calcareous blue shale and thin blue crystalline limestone layers. Likewise the conditions became again favorable for a profuse growth of marine animals, especially of corals, bryozoa and brachiopods, some layers of the Liberty teeming with their remains. These fossils abruptly begin in their fullness in the very bottom layers of the Liberty which in this respect as well as in lithic character contrast strongly with the underlying Waynesville and attest a decided and comparatively sudden change of conditions in this region. During this epoch clear and muddy water seem to have alternated rapidly in this region resulting in alternating thin layers of crystalline limestone and coarse calcareous shale. In parts of Ohio conditions were different from those prevailing in this region for there the Liberty is mostly limestone.

SALUDA EPOCH.

The Saluda epoch, which succeeded the Liberty apparently without an intervening time of notable length, was introduced by the deposition of coarse muddy sediment similar to that intercalated between the thin limestone layers in the upper part of the Liberty. After the deposition of a few feet of such sediment, forming a coarse lumpy mud rock, a time of clear water ensued in which *Columnaria* and *Tetradium* reefs and the few associated thin pure limestone layers in the basal part of the Saluda originated. This condition was soon succeeded by a very different one—a condition or combination of conditions that had not been preceded in the known geologic history of the region. These conditions were those under which the material of the thick bedded, highly magnesian, and sandy part of the Saluda was formed.

The main features of difference are the presence of a large proportion of magnesian carbonate and of fine quartz grains. The former may indicate an arid climate accompanied by rapid evaporation and concentration of the sea water leading to the formation of the double carbonate of lime and magnesium, as in the lagoons of coral islands at the present time. Complete dessication of the sea, at least locally and temporarily, is made certain by the presence of sun cracks (shrinking cracks) in the limestone. The almost total absence of fossils in the main Saluda limestone may be interpreted as further evidence of dessication, while the dessication reciprocally explains the absence of fossils. The source of the quartz grains is a matter for speculation. They could have been borne either by water or wind, but their source must have been distant from this area, since no quartz-bearing rocks are known nearer to that area in Saluda time than the Appalachian Mountains on the east, the Canadian or northern Wisconsin areas on the north, or the Ozark region on the west. Since the rocks of Saluda age to the north and east of this region in Indiana and Ohio and in the Appalachian Valley are all limestone and shale supposedly without notable quantity of quartz grains, the quartz grains are believed not to have come from the east or north. Hence it is thought that they came from Wis-

consin or the Ozark region, and as the quartz-bearing Saluda beds are best developed nearest the Ozark area, and may extend far eastward from that area beneath the Illinois basin, and as there is sandstone of about the same age as the Saluda at Thebes in Southern Illinois, the Ozark area is regarded as the most probable source of the quartz. It is recognized also that the quartz may have been derived from secondary sources, as from an area of pre-Saluda limestones and shale which may have been, in some region that drained into the Saluda sea, raised into land, whereon a possible very minute proportion of quartz sand which the limestone and shale may have contained was, by long weathering, concentrated in sufficient quantity to supply the sandy material of the Saluda.

In the last part of Saluda time represented by deposits in this region the conditions just discussed were succeeded with comparative suddenness by clear water in which was laid down the pure fossiliferous limestone of the Hitz member, which stands out in marked contrast to the sandy, magnesian, nonfossiliferous beds laid down just before the Hitz.

UNRECORDED INTERVAL.

There is an unrecorded interval of considerable length between the Hitz limestone member of the Saluda and the succeeding Brassfield limestone. The evidence of this interval is the absence in this region of beds that are present elsewhere, as in Illinois and New York, between the Saluda and Brassfield limestones. This matter was described in more detail on a previous page. In this interval there was a rather extensive emergence of sea bottom to form dry land, followed by resubmergence and the beginning of the deposition of the Brassfield limestone. Such oscillations were of fairly common occurrence in the history of this region.

SILURIAN PERIOD.

Like the preceding period, the Silurian was one almost entirely of limestone or dolomite deposition. Subordinate beds of calcareous shale were also laid down.

BRASSFIELD EPOCH.

This region seems to have been submerged during a small part only of the Brassfield epoch; for the 3 feet or so of Brassfield limestone represents but a thin portion of the strata that in other regions were deposited during the epoch. This area was covered by a clear sea in which animal life throve and in which was accumulated a pure and fossiliferous crystalline limestone. It is probable that the Brassfield sea was connected with the Gulf of Mexico since the Brassfield fauna extends southward to the Coastal Plain deposits of Alabama and probably farther south beneath those deposits.

UNRECORDED INTERVAL.

The deposition of the Brassfield limestone was followed by a long interval of time which is not recorded by rocks in this region but, in New York and Pennsylvania, is recorded by strata of earlier Clinton and probably of Upper Medina age. Whether the absence of the earlier Clinton and late Medina rocks from this part of Kentucky is due to nondeposition of sediment, although the region may have been covered by water, or was due to the emergence of the region as land above sea level during early Clinton time, are questions that can not be answered with certainty, although the last described condition is believed to be the more probable. From the thickness of the Medina and Clinton rocks present in New York and Pennsylvania, but unrepresented in Jefferson County, it is certain that the unrecorded interval is a long one.

OSGOOD EPOCH.

However long the dry land period just described may have existed, the region once more sank below the level of the sea and in the invading water the lower limestone of the Osgood formation was the first bed to be deposited. However, limestone deposition was soon ended by the

influx of calcareo-argillaceous sediment composing the lower shale of the Osgood. This change may have resulted from an increased altitude of the land supplying the terrigenous material, which in turn resulted in increased erosion and increased quantities of sediment. It may have resulted from increased precipitation which would likewise cause increased supply of sediment, or it may have resulted from change in shore lines or changed connections with other bodies of water with accompanying change in the strength or direction of the sea currents by which the material was transported so that much clayey matter was brought to the region while but little was brought in during the time that the lower thin limestone was being deposited.

The above speculations serve to indicate the variety of explanations possible for changes in the lithic character of strata. These lithic changes follow upon changes in physiography or meteorology.

After the deposition of the lower shale of the Osgood, the conditions attending the deposition of the lower limestone of the Osgood were repeated and the upper limestone, very similar to the lower, was laid down. This limestone is highly magnesian and that feature together with the scarcity of fossils, may indicate partial dessication of the sea water. The last episode of Osgood time in this region was the deposition of the thin, soft, calcareous upper shale of the formation which indicates the return of conditions similar to those prevailing when the lower shale was deposited. This rapid change may point to meteorologic rather than physiographic causes; for meteorologic conditions can readily be conceived as being much less stable than physiographic.

A notable feature of the Osgood in the Kentucky region is the scarcity of fossils which are so very abundant in the corresponding Rochester shale, the topmost member of the Clinton formation of New York. This again may be attributed possibly to concentration of the saline contents of marine water in a partly dessicated shallow interior basin in the Kentucky region while more normal conditions prevailed in New York.

LAUREL EPOCH.

In the Laurel epoch a more permanent state persisted, as a result of which the fairly uniform Laurel dolomite was deposited. The region appears to have been covered by clear and perhaps somewhat concentrated water to which the magnesian contents of the dolomite may be due. This sea was of wide extent, for the dolomite formed in it spreads from Tennessee to New York and Wisconsin. The Kentucky region did not seem suitable to animals at this time, for fossils are very scarce in the dolomite.

WALDRON EPOCH.

A change of brief duration but affecting a large area followed the deposition of the Laurel dolomite. A uniform bed of clayey and calcareous material constituting the Waldron shale was laid down over an area extending from Indiana to Tennessee. In parts of Indiana and Tennessee the Waldron is crowded with fossils, showing that animals lived in great numbers in some localities, the most notable of which is Waldron, Indiana, from which the shale takes its name. In Jefferson County, however, the shale is nearly devoid of fossils and evidently the region did not afford animals a congenial habitat in Waldron time. It is possible that this interruption of magnesian limestone deposition by that of largely terrigenous material was caused by a brief period of unusually heavy precipitation and consequent increased erosion of the low limestone lands bordering the Waldron sea and the transportation and distribution of the sediments by currents and other agitations set up in the shallow sea by the influx of great quantities of flood waters from the land.

UNRECORDED INTERVAL.

As shown previously, there is a break in the sedimentary record immediately above the Waldron shale. The events of this time in the Louisville region are unknown, but in Southwestern Tennessee the interval is characterized by over 200 feet of highly fossiliferous shale and limestone showing that that region was sub-

merged and deposition was unbroken, except possibly for brief periods. The assumption that this part of Kentucky was raised a little above sea level, slightly eroded, and then resubmerged in the interval, seems as probable as any.

LOUISVILLE EPOCH.

The Louisville epoch began with the resubmergence of the Kentucky-Indiana area at the close of the unrecorded interval and continued until 40 to 100 feet of limestone was accumulated. Conditions similar to those prevailing during the Laurel epoch seem to have existed, for the Louisville contains a considerable portion of high magnesian limestone.

The presence of notable proportions of argillaceous and siliceous impurities in the limestone indicates that the Jefferson County region was not far removed from land in some directions and probably to the east. The Louisville sea was, at times at least, evidently a congenial habitat for various kinds of the animals of the time, especially for corals, crinoids and brachiopods. The closing part of the epoch was especially favorable to these forms, the remains of which are so abundant in the topmost siliceous and argillaceous layers of the limestone.

UNRECORDED INTERVAL.

The Louisville epoch is succeeded by an unrecorded interval of great length during which great thicknesses of rocks were deposited in other parts of the United States, notably in Pennsylvania and New York. The unrecorded time extends from the close of Niagaran time through Cayugan time, ending the Silurian period, and through Helderbergian and Oriskanian time of the early part of the Devonian period to the Jeffersonville (Onondaga) epoch.

As to the course of events in this part of Kentucky nothing is known. Speculation based upon known geologic principles alone is possible. Any event or course of events that resulted in the absence of any rocks in this region, deposited in the long interval between the Louisville and Jeffersonville epochs, may be legitimately postulated as a possibility. All hypotheses may apparently be assembled under two general classes as follows: 1st, The region received no sediment during the unrecorded time, or 2nd, sediment was deposited in parts of the time but later eroded away.

The failure of sedimentation according to the first hypothesis may be explained in any one of three ways: 1st, either the region subsided to great depths so that no or very little sediment reached the sea bottom, as in the deeper parts of the ocean at the present time; 2nd, water currents analagous to the Gulf Stream may have moved over the region during the time and prevented sedimentation by carrying such fine sediment as the water held in suspension across the region to deposit it elsewhere; or, 3rd, the region was dry land during the time and of course received no sediment. The first two explanations assume the continuous submergence of the region.

As to these explanations the first seems untenable on account of the very great movement of the sea floor demanded in so short a time, a movement of many thousand feet, and change from the comparatively shallow sea of Louisville time to a deep sea comparable to the deeper part of the oceans not receiving appreciable amounts of sediment at the present time. As to the second explanation the objection is that the area involved is too broad. Oceanic currents such as the Gulf Stream, are of sufficient strength to be effective only in comparatively narrow courses. The third explanation, namely, that dry land existed all the time, seems to be objectionable because it assumes such a long period during which the land was practically at sea level, especially in view of the known oscillatory behavior of the earth's crust in this and other regions in the preceding epochs already described.

Under the second general hypothesis, namely, the region was dry land part of the time and submerged part of the time, two general subsidiary hypotheses may be proposed, either of which would explain existing conditions. The first is that subsidence continued for a long time beyond the end of the Louisville epoch, during which rocks of later age were deposited and later the region was slowly and nearly uniformly uplifted above the sea. As soon as the land appeared erosion began and wore the rocks away evenly down approximately to sea level

and to the top of the existing Louisville limestone when the region again sank below the sea, and the deposition of the Jeffersonville limestone upon the evenly eroded surface of the Louisville took place, producing such even and closely knit contacts as that described on a previous page, and illustrated on Plates 32 and 33. It is assumed that the subsidence took place to the west of this region first and proceeded eastward so that the sea transgressed the land from the west and the strand line moved eastward at the same time. This supposition is supported by the fact that the Jeffersonville limestone thins out eastward as if only the upper and last deposited layers extended to the eastern limit of the Jeffersonville sea. This idea of eastward transgression applies only to the west side of the Cincinnati dome. As a matter of fact the Onondaga ("Corniferous") sea, to use the more general name, transgressed the Cincinnati dome from all directions, west, south, and east.

The second and most likely hypothesis is that there was a number of cycles in the unrecorded interval with alternating relatively brief periods of subsidence and sedimentation followed by emergence and erosion.

This hypothesis agrees best with the preceding history of the region for, as already described, there had been a number of such oscillatory movements in Richmond and Niagara time, which probably was no longer than the unrecorded interval under discussion.

DEVONIAN PERIOD.

The early part of the Devonian period is unrecorded in this region; the middle part is recorded in existing limestone formations, and it is uncertain whether the upper part of the Devonian is recorded. If it is it is by the New Albany shale, the age of which is in dispute.

JEFFERSONVILLE EPOCH.

The Jeffersonville epoch began with the resubmergence of the region as described above. It was an epoch of clear, pure water as shown by the analysis of the limestone (see table), and by the coral reef conditions. These organisms then, as now, probably required clear and warm water. One can easily imagine the sea bottom of the time in the vicinity of Louisville as covered with a profuse growth, in the congenial water of a sub-tropical clime, of brightly colored coral polyps of many sizes and varieties, similar in appearance to the submarine coral forests of the Bahama Islands of today. The corals flourished best in the earlier part of Jeffersonville time, but later other forms such as the bryozoa, brachiopods, gastropods and pelecypods predominated. Most of these, as they perished in the course of nature or by accident, left their hard parts upon the bottom of the shallow sea to be slowly buried, and, after long ages, to be exposed in their rocky burial place, lying as they fell, to give to man an illuminating glimpse into the conditions of the distant geologic past.

UNRECORDED INTERVAL?

In this region no rocks corresponding to the Marcellus shale of New York, which succeeds the Onondaga ("Corniferous") limestone are known, so it is thought that some time elapsed between the end of the Jeffersonville and the beginning of the Sellersburg epoch.

SELLERSBURG EPOCH.

In the Sellersburg epoch two limestone strata of very different character were laid down in this area, the Silver Creek and Beechwood limestones already described. The conditions under which the fine-grained magnesian Silver Creek (hydraulic) limestone was deposited must have been quite different from those under which the coarse-grained Beechwood limestone was deposited, although we do not know just what the differences in the environment were. It may be surmised that a semi-arid climate with rapid evaporation and concentration of sea water prevailed in Silver Creek time and the reverse condition in Beechwood time. The change from one condition to the other may have involved considerable time and there may be a small hiatus between Silver Creek and Beechwood time. Such a supposition is supported by the irregularities near the contact, the wedging out of the Silver Creek to the southeast and the phosphate nodules in the basal layer of the Beechwood. All these phenomena have been fully described and are illustrated on Plates 41, 42 and 43.

As to the phosphatic nodules they seem clearly not to have formed in *situ* in the limestone in which they are now included. It is suggested that they originated in the shallow sea bottom during a time of little or no deposition of calcareous or other sediment following the close of the formation of the Silver Creek limestone. The phosphate may have been derived largely, if not principally, from a multitude of ostracod shells which are phosphatic in composition, although phosphatic substance may have been derived from the decomposition of other organic matter. The irregularities of the bedding corrobates the view of shallow water in which the slowly deposited sediment was irregularly distributed by wave and current action and at the same time the nodules formed by concretionary actions were rolled about and polished and finally incorporated in the unconsolidated calcareous sediment now forming the basal layer of the Beechwood limestone.

NEW ALBANY EPOCH.

The New Albany epoch was introduced by one of the most remarkable changes that occurred in the whole history of the region. The deposition of the Beechwood limestone was followed by that of the New Albany shale apparently without break in sedimentation for any considerable length of time. The Beechwood is of Hamilton age and the basal part of the New Albany is of Genesee age, the succession being the same as in the type region of the Hamilton and Genesee where no break is recognizable between the two. Where exposed at Louisville the Beechwood-New Albany contact is generally very sharp and even, but in places the contact is less definite, a thin layer of black shale being followed by a thin layer of limestone and then the main body of the New Albany. This seems to indicate the beginning of black shale deposition before the close of limestone deposition and a continuity of deposition from the one to the other. However, the relations described above may have been produced by sea bottom erosion and redeposition after the deposition of the New Albany began. Also it is not known that the top of the Beechwood limestone corresponds in time to the top of the Hamilton. It may be older, in which case a time break of short duration intervened between the Beechwood and the New Albany.

The feature which most particularly distinguishes the New Albany from all the other formations in the region is its black color, which is produced by carbonaceous matter, all of which apparently is of vegetal origin. The conditions producing this shale seem to have been low lands bordering a shallow sea. From the low land was derived only fine sediment such as composes the shale and on this land grew an abundant terrestrial vegetation and perhaps also in the shallow water, which may have been of brackish composition, aquatic plants flourished. From this vegetation, the larger remains of which are preserved in some regions, by partial decomposition or by maceration, was derived the finely divided carbonaceous matter or small fragments of tissues which, disseminated by the water and ultimately incorporated with the fine sediment, give to the shale its black color.

If it be accepted that the New Albany shale is all of

Devonian age, as the writer is inclined to do, it seems likely that the conditions sketched above persisted through a large part of Portage and Chemung time as well as through Genesee time. If, however, the view of which Ulrich is the chief advocate, be accepted, namely that all but the lower 15 feet or so of the New Albany as developed at Louisville is of Carboniferous age, the history of the time represented by the black shale would be quite different. According to this view no rocks of Portage or Chemung age remain in the region if any were deposited. On that view the present conditions are the same as they would be if after the deposition of the Genesee part of the shale, the region became dry land and so remained through Portage and Chemung into early Mississippian (Carboniferous) time when the region was again submerged and conditions identical in character to those of Genesee time were repeated in the region. Since the Portage and Chemung are in Pennsylvania at least 5,000 feet thick the time involved in such a break would be very long indeed.

The subject is a complex and debatable one which does not admit of full discussion here and on which the writer prefers not to take a definite stand at present, although inclined to the Devonian side of the argument.

CARBONIFEROUS PERIOD.

The Carboniferous period, so far as represented by deposits in this county, is divided into the New Providence, Kenwood, Rosewood, Holtsclaw, Warsaw and Spergen epochs. The region seems to have been covered by the waters of the sea without interruption during deposition of the rocks now present. During the first four epochs shale and sandstone deposition, and during the last limestone deposition prevailed.

UNRECORDED INTERVAL?

In this county the New Albany shale is succeeded by the New Providence, but in Northwestern Tennessee it is maintained by Ulrich and Bassler that between beds corresponding in age to the New Albany and New Providence, another formation intervenes, which they call the Ridgetop shale. The Ridgetop being unrepresented in this region there is an unrecorded interval of short duration between the New Albany and New Providence and if all the New Albany is Devonian, this interval falls between Devonian and Carboniferous deposition in this region. The existence of this interval is also indicated by the absence of the Rockford limestone which in Indiana lies between the New Albany and the New Providence, and it is further supported by the band of phosphatic nodules between the two formations, the nodules indicating a period of shallow water and organic accumulation such as might attend a very slow submergence of a low lying land area.

NEW PROVIDENCE EPOCH.

During the New Providence epoch fine clay was supplied to the water covering this region. Near the middle of the epoch animals were abundant locally, and thin limestone layers largely composed of crinoidal joints and bryozoans are now present in the shale at such localities, the most notable of which in this part of Kentucky are Button Mould Knob and Kenwood Hill. In the latter part of the epoch considerable iron seems to have been included in the sediment which later was segregated to form the numerous carbonate of iron nodules in the upper

part of the New Providence shale. The source of the New Providence, as well as of the later sediments of the Osage group, probably was in land lying southeast of this region, for in that direction the sediment of the same time was coarser than in Jefferson County, while to the west and northwest the equivalent rocks of Burlington and Keokuk age are predominantly limestone and chert, which shows that clear water prevailed in that direction and that the terrigenous sediment of the New Providence could not have come from that quarter.

KENWOOD EPOCH.

Conditions changed somewhat at the beginning of the Kenwood epoch chiefly in such a way as to bring into the region at times from some source a considerable amount of fine quartz sand for the sandstone layers by which the Kenwood sandstone is distinguished.

ROSEWOOD EPOCH.

During the Rosewood epoch coarse siliceous sediment was the principal material supplied to this region. For a short time after the middle of the epoch animals lived upon the bottom in fair abundance and at the same time and possibly as a result of the growth of the animals the thin limestone lenses were formed that lie somewhat above the middle of the formation.

THE HOLTSCLAW EPOCH.

The Holtsclaw epoch was of short duration in this region. Most of the sediment received was very fine quartz sand, out of which the Holtsclaw sandstone is composed. The sea probably had a clean, sandy bottom on which large brachiopods lived and died, leaving their shells in the sand which preserves their imprints to this day.

According to accounts, on going northward in Indiana along the outcrop of the Mississippian rocks, the Holtsclaw sandstone phase descends lower and lower with the distance until it practically occupies the whole interval occupied in this region by the Kenwood and Rosewood. This seems to show that the sand was transported from some northern source southward to this re-

gion along the eastern border of the Osage sea upon the western limb of the Cincinnati anticline. Westward and southward the equivalent rocks of Keokuk age are mostly limestone and chert. Therefore the terrigenous sediment of the Osage ("Knobstone") group of Indiana and Central Kentucky could hardly have come from those directions.

WARSAW EPOCH.

It is supposed that the deposition of the Warsaw formation in this region followed that of the Holtsclaw sandstone without cessation of deposition, at least for any notable length of time. The patches of thin oolitic limestone and the apparently larger areas of glauconitic clay at the same horizon probably were deposited slowly in shallow water, the oolite in protected lagoons or basins receiving very little terrigenous sediments; the glauconitic clay in other areas in which a small amount of calcareous clayey sediment was slowly laid down.

It is probable that shallow lagoonal waters separated by sand bars may have persisted for a time succeeding the cessation of the Holtsclaw sand deposition. During this time the Warsaw fauna of the oolitic limestone slowly migrated into the region. The deposition of the oolite and clay was followed by that of siliceous, argillaceous and calcareous sediments in various proportions in different places so that at a given horizon comparatively fine limestone was formed at one place; a mixture of materials, forming an impure limestone, at another; and argillo-siliceous matter, forming shale, at another. Animal life of certain kinds flourished abundantly at times in some localities, but judging from the scarcity of fossils in most of the formation, the sea seems to have been rather sparsely populated for most of the time. The most abundant forms now found fossil were bryozoans, sponges and crinoids, the hard parts of the bryozoans and the siliceous spicules of the sponges being abundant in some chert layers and the joints of crinoids forming a large part of limestone layers in the southwest part of the county and in Bullitt County.

The formation of the geodes so prominent in some parts of the Warsaw may be touched upon here, although

the bodies are not original but of recent and superficial origin. The geodes are hollow globular masses of silica which form in the superficial parts of the beds in which they occur by the process of segregation of silica disseminated through the bed. In many cases the segregation of silica begins in fissures or cracks in fossils and continues to accumulate until the fossil is split widely apart into separate fragments and finally destroyed altogether. This method of formation prevails in the New Providence shale of Kenwood Hill and has been fully described by Bassler.* The writer does not believe, however, that the geodes of the Warsaw had fossils for their nuclei for the reason that fossils are practically absent from the beds in which the geodes are most abundant. The segregation in this case may have begun along lines of intersection of thin cracks in the rocks, the deposition of silica in solution in circulating water beginning in such situations and continuing, pushing the surrounding rock matrix away, until the growth ceased.

Whatever the details of growth, it seems to be generally accepted that geodes were formed by segregation either about some center as a point of origin from which the geode grew outward or by the inward deposition of silica from the walls of a cavity. Just how, under the first named mode of growth, the geode could be hollow is not understood. This feature better accords with the second named hypothesis of their origin.

SPERGEN EPOCH.

The Spergen epoch in this region was introduced with the deposition of comparatively pure limestone which continued in the main to the end of the epoch. It is not unlikely that there was an expansion of the sea areas and a recession of the shore lines, so that owing to greater distance of its source, little or no terrigenous sediment reached the region.

*Bassler, R. S. The Formation of Geodes with Remarks on the Silicification of Fossils, U. S. Nat. Mus. Proc., vol. 35, pp. 133-154, 1909.

POST-SPERGEN TIME.

Except for the glacial outwash of recent time partly filling the ancient valley of the Ohio, no records in the form of rock strata remain in Jefferson County for the immensely long period between the Spergen epoch and the present time. This great time includes all the Paleozoic era subsequent to the Spergen epoch, all the Mesozoic and Cenozoic eras represented along the Atlantic and Gulf coasts and in the Rocky Mountain region by strata amounting to thousands of feet in thickness. Some events for this time may, however, be reasonably inferred from the topography, stratigraphy and known geologic history of the immediately surrounding country and of the Appalachian Province generally. Thus it seems probable that Jefferson County was covered by the sea during the remainder of Mississippian time, and that the St. Louis, the Ste. Genevieve and Chester formations of the west were deposited over the region and across a part of the area of the Cincinnati anticline, so that they were continuous with rocks of the same age east of the anticline in eastern Kentucky. Likewise it is possible that the Coal Measures of Eastern and Western Kentucky were joined together by a continuous sheet of rocks extending across the anticline. Whether any rocks of Permian age closing the deposition of the Paleozoic era ever extended across this area is a question upon which there is not even a basis for a conjecture.

THE APPALACHIAN REVOLUTION.

After the latest Paleozoic rocks had been deposited, a revolution took place in the course of geologic events in the Eastern United States. Hitherto the whole interior region had been sinking. Submergence beneath marine water with sedimentation had been the rule. But after the latest Paleozoic sediments had been deposited, the course of events was reversed. Uplift and erosion took the place of subsidence and sedimentation and have continued to the present time. This reversal from constructive to destructive conditions and geologic processes is known as the Appalachian revolution. This revolution was accompanied by great deformation of the rocks in the Appalachian Valley, but in the Jefferson County region the only effect upon them was a broad uplift with perhaps gentle warping such as is delineated by the structure contours of the geologic map.

MESOZOIC AND CENOZOIC ERAS.

During the Mesozoic and Cenozoic eras, this region was land, like the Appalachian Province generally, and being land and subject to erosion, no records of its history are preserved except those of the latest events of the Cenozoic era. Some of the earlier events may, however, be inferred from existing topographic features of the surrounding regions, especially the elevated region of Eastern Kentucky and Tennessee. These events being probably common to the entire Appalachian Province have been stated in the History of the province on previous pages, and only need to be briefly restated here. After the Appalachian revolution a succession of uplifts, alternated by periods of stability during which the uplifted land was eroded away to a greater or less depth, prevailed throughout the Mesozoic and Cenozoic eras. By the beginning of the Cretaceous period the land was worn down by erosion to a peneplain near sea level and the streams assumed their present courses. There is evidence that one or more extensive peneplainations took place in earlier times but the Cretaceous peneplain is the earliest of which the geologic date seems to be at all well established. This date is fixed by the fact that deposits

of Cretaceous age overlap the margins of the peneplain in New Jersey and the Gulf States. Presumably the great reptiles (Dinosaurs) of Jurassic and Cretaceous time roamed over the surface of this peneplain, but no remains of such have been preserved.

After the formation of the Cretaceous peneplain the region was again uplifted about 500 feet and again peneplained by erosion except the Cumberland Plateau region. Remains of this second peneplain are preserved on the hill tops of eastern Kentucky about 500 feet below the level of the old Cretaceous peneplain. A third uplift raised the Appalachian Province another 500 feet and a third period of erosion reduced extensive areas to a third peneplain including the Highland Rim and Lexington Plain the trenched surface of which is still preserved in Central Kentucky and which at the time of its completion included the surface of Jefferson County. Even yet the tops of the knobs in the southern part of the county reach nearly up to the ancient level of the Highland Rim peneplain. From the time required for the second and third uplifts and the erosion of a thickness of 1,000 feet of rocks down to the third peneplain level, it is believed that that peneplain was formed in the Tertiary period and it is commonly spoken of as the Tertiary peneplain. After the completion of the Tertiary peneplain a fourth uplift of about 500 feet occurred. This was followed by the erosion down about to the present surface level of the flat area extending from the foot of the Knobs northeast through the central part of Jefferson County, and of an extensive area in Indiana north of Jefferson County. A fifth uplift then ensued and the Ohio River intrenched itself in the last formed surface to a depth of almost 150 feet and the side gorges of the present tributary creeks were cut in the river bluffs. At this time the river followed a different course from its present one in the vicinity of Louisville. It continued in a direction slightly southeast of its present direction northeast of Louisville and passed southwestward beneath the central part of the city. Wells drilled to rock bottom at various points show that the old bed of the river was about 360 feet above sea level, whereas the present rock bed along the rapids is 400 feet above sea level, a differ-

ence of 40 feet. The alignment of the bluffs northeast of Louisville and the west side of the Knobs southwest of the city indicate the ancient river bluffs. The river probably meandered more or less over a wide flood plain between this line and the bluffs on the Indiana side.

The deep, narrow valleys cutting the bluffs northeast of Louisville, plainly intrenched in a nearly flat, level, continuous surface, are highly suggestive of youth and seem to point to a recent uplift of the region accompanied by the usual rapid incision of the valleys. A mile or so back from Ohio River these small valleys have rock floors, but nearer the river they have been silted up, in part probably in glacial times and in part in later times when the valleys have been occupied by backwater from the river at flood time. The rock bottoms of the side valleys doubtless descend beneath the silt now occupying their lower parts to join with accordant level the rock bottom of the river beneath its alluvial filling. It is not unlikely that the uniform upland surface of this part of the county (disregarding the valleys) is a preglacial base level of erosion and that the county was uplifted 200 feet or so also in preglacial times and that the side valleys, though showing the character of youth, were yet eroded mainly in preglacial times.

The low ground between the Poplar Level road and the Knobs which is flooded at times and which before ditching was a permanent swamp, presents some interesting questions, especially that of its origin. The rock floor of this area is only 6 to 20 feet below the surface and probably over a considerable area is about 440 feet above sea level. The low altitude seems to be due to erosion. The underlying rock is New Albany (black) shale which is not especially easy to erode, so that easily erodible rock cannot be assigned as the reason for the low area. There seem to be two possible explanations. The area may have been drained by Pond Creek, which may have had a deeper channel in preglacial times than at present so that its fall gave it sufficient transporting and eroding power to accomplish a work that is seemingly beyond its present ability. Or the area may have been drained by a stream flowing northward between Louisville and Highland Park through a now buried channel

at the level of the preglacial Ohio. Such an outlet would have been much shorter than that by Pond Creek and the fall would seemingly have afforded erosive power amply sufficient to have eroded the area to its low level. The fall of such a stream would have been about 100 feet in 4 or 5 miles, for the bottom of the old preglacial channel of Ohio River beneath the southeastern part of Louisville is only about 360 feet above sea level.

During all the time in which these profound changes of the land surface were in progress, there were equally important changes in the biologic realm. This region has doubtless been covered with vegetation since the Appalachian revolution, but there has been a constant succession of different kinds of plants, from early Mesozoic to the present, the records of which have not been preserved owing to constant destruction of the land by erosion so that no deposits which could have preserved plant remains have survived. Deposits in the Atlantic and Gulf Coastal plains have preserved such remains which show clearly the succession of plant forms which must have lived in this region in Mesozoic and earlier and greater part of the Cenozoic era. Our common deciduous types of forest trees began in Cretaceous time and probably occupied this country from then on. As with the plants so with the animals. In Mesozoic time dinosaurs and other reptilian forms probably inhabited this region for their remains exist in deposits of that time in the Atlantic and Gulf Coastal plains deposits comparatively near this region. In the earlier (Tertiary) part of Cenozoic time a great variety of mammals of strange types but approaching nearer and nearer to modern types as time went on must have roamed the forests and plains, but none of their remains now exist in this region nor in the Appalachian Province generally because any deposits, whether made in lakes or swamps, which may once have contained their remains have been eroded away.

This brings the geologic history of the county down to the last notable episode, namely the glacial epoch.

PLEISTOCENE EPOCH.

In this epoch an ice sheet covered the northern part of the continent, its southern margin lying just to the north of Jefferson County. The ice sheet bore great quantities of debris, mud, sand, gravel and bowlders picked up in its movement across the country and, upon melting at its southern margin, so much of this debris was discharged into the Ohio that it could not carry it all, but dropped it in its bed. As a result the valley was filled to a depth of about 150 feet so that the top of the river fill was about 500 feet above sea level, as shown by remnants of the detritus now remaining at or near that level. With the recession of the ice front and the return to normal drainage conditions the river water gathered into a single channel, which at Louisville was, owing to the local configuration of the valley surface, located along its present course northwestward over the "Falls" instead of along its preglacial course through the heart of the city. Such stream diversions, on account of which streams flow in places through rock gorges on the margins of their old valleys, are common in glaciated regions. The gorge below Niagara Falls and the Portage gorge in New York are notable examples, both being due to the diversion of the rivers from their pre-glacial courses.

With this return to normal conditions the Recent epoch began. In the Pleistocene or Glacial epoch Arctic animals, such as the musk ox and reindeer lived as far south as Kentucky and with them were associated the mammoth and mastodon.

RECENT EPOCH.

Since the readjustment of its channel the river has in the Recent epoch entrenched itself 80 to 100 feet below the original top of the glacial fill and in the same time 20 to 40 feet of the latter has been removed by erosion from the top of the whole surface of the glacial outwash deposit. In this way originated the alluvial terrace bordering the river both above and below Louisville and lying 20 to 30 feet below the present general level of the glacial outwash terrace upon which the city stands. In the rest of the county the surface in this epoch has been subject to the sculpturing activity of wind and water, but

owing to the shortness of the time involved, comparatively minor effects have been wrought and the surface of the county probably does not differ notably from its preglacial surface. The plant and animal life of the region during the Recent epoch has been pretty much the same as that of the present.

In very recent time the natural levee opposite the mouth of Beargrass Creek was formed. This levee was the result of the checking of the velocity of the river water, probably owing largely to its coming into contact with the transverse current from Beargrass Creek. Such slackening of velocity usually results in deposition of sediment when the water is heavily loaded with the same.

CHAPTER 7.

MINERAL RESOURCES.

General Statement.—The mineral resources of Jefferson County are all of low rank. The principal are limestone, clay, shale, sand, gravel, a little gas, and a large amount of oil that could, though probably not with profit at the present time, be distilled from the New Albany shale. To these should be added mineral waters.

Some of the limestone formations of the county furnish building stone and road metal. There is but little limestone suitable for cement or chemical lime, but probably rock suitable for agricultural lime is fairly abundant. Clay and shale from some formations are utilized on a large scale for building brick. Clay from the county is also used in the manufacture of cement. Sand and gravel are obtained from the river bed and to a small extent from the glacial outwash.

The county has no high rank mineral deposits such as precious or semi-precious metals. It has no coal deposits. Iron might be considered an exception to this statement owing to the presence of considerable iron in the form of iron carbonate nodules in the upper part of the New Providence shale. These nodules are, however, neither of such quantity or richness in metal as to be mined with profit and are negligible as a mineral resource.

LIMESTONE.

Building Stone.—The most important use of limestone in the county is for building purposes, including masonry and curb stones. For these purposes, stone from the Louisville, Laurel and Saluda formations is utilized.

The Louisville limestone on Beargrass Creek in the eastern environs of Louisville where are located the principal quarries, has a known thickness of 63 feet and is

somewhat thicker. It lies in even beds or layers ("ledges"), varying from 9 inches to nearly 5 feet in thickness as shown in Plate 57. A detailed section follows:

Section of the Louisville Limestone at Shanks Quarry, on Beargrass Creek in the Eastern Part of Louisville, Giving Quarrymen's Names of the Layers ("ledges.")

		Ft.	In.
Jeffersonville limestone:			
18.	Thick bedded, coarse-grained, dark gray or brownish, part of "Iron ledge," used as crushed rock only. Analyses G-3612 and 3613	16	3
Louisville limestone:			
17.	Fine-grained bluish, siliceous (cherty) and argillaceous, weathers to clay; highly fossiliferous; principal source of Louisville limestone fossils. Lower part of "Iron ledge," crushed rock only	4	8
16.	Fine-grained, bluish, weathers buff; highly magnesian, "Top blue ledge." Analysis G-3614	4	4
15.	Fine-grained, light-gray. Chert in top foot. "Gray ledge." Analysis G-3615	4	7
14.	Like No. 15 with 3 to 4 layers of chert nodules. "Oyster ledge." Analysis G-3616	3	9
13.	Like No. 15, full of chert nodules. "Flint-flagging." Analysis G-3617	1	3
12.	Like No. 15, two bands of chert nodules. Analysis G-3618	3	10
	Nos. 12 and 13 together called "7-foot ledge."		
11.	Fine-grained, light bluish-gray, weathers buff. Highly magnesian. "Big blue ledge." Best building stone. Analysis G-3619	4	5
10.	Dark-gray, very hard. "Hard ledge." Anaylsis G-3620	2	5
9.	Like No. 10, "Hard curb." Analysis G-3621	2	8
8.	Bluish-gray, "22-inch ledge." Analysis G-3622	1	10
7.	Gray, hard, uniform texture, "Blue captain." Analysis G-3623	2	5
6.	Like No. 7, "Paving ledge." Analysis G-3624	2	10
5.	Like No. 7, "Little flag." Analysis G-3625		9
4.	Like No. 7, "Big flag." Analysis G-3626	1	0
3.	Dark-gray, hard, 4 layers, "Bottom Curb ledges." Analysis G-3627-3630	6	10
2.	Dark-gray, many dark bands, "Granddad ledge"	2*	
1.	Dark-gray "Great granddad." Analysis G-3631	8*	
		63	5

*More or less.

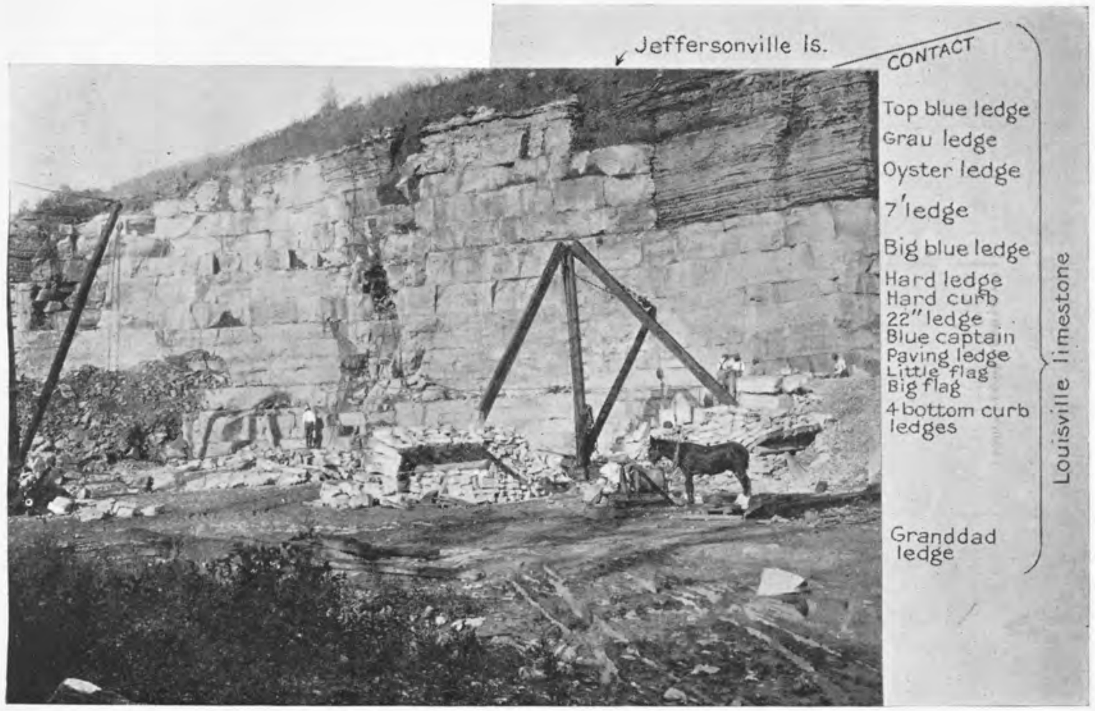


Plate 57.
Louisville limestone in Shanks' quarry in the eastern part of Louisville. Looking east.

Plate 58.
View on Bardstown road in the eastern part of Louisville. Shows foundations, retaining wall, and curbs of Louisville limestone.

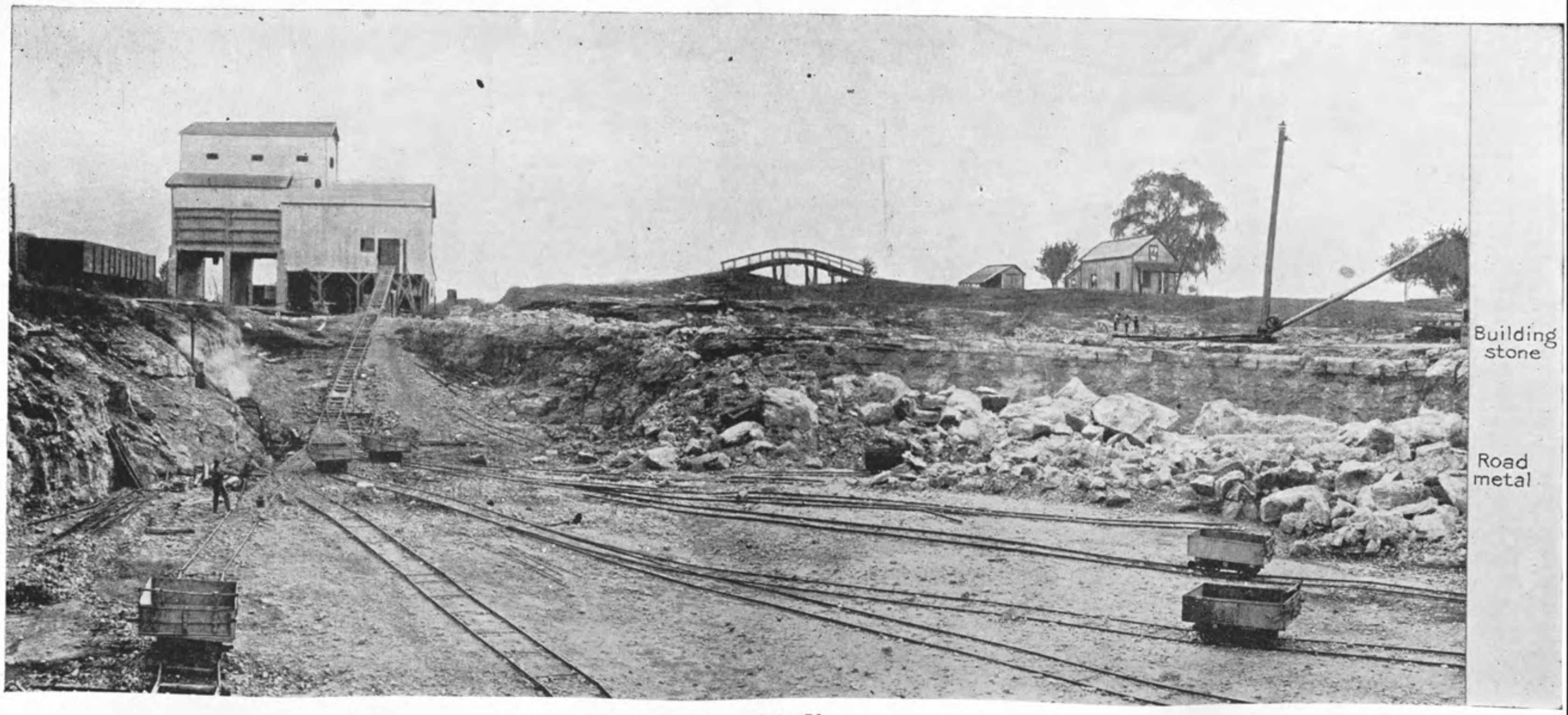


Plate 59.
Panoramic view in the quarry at Tucker.

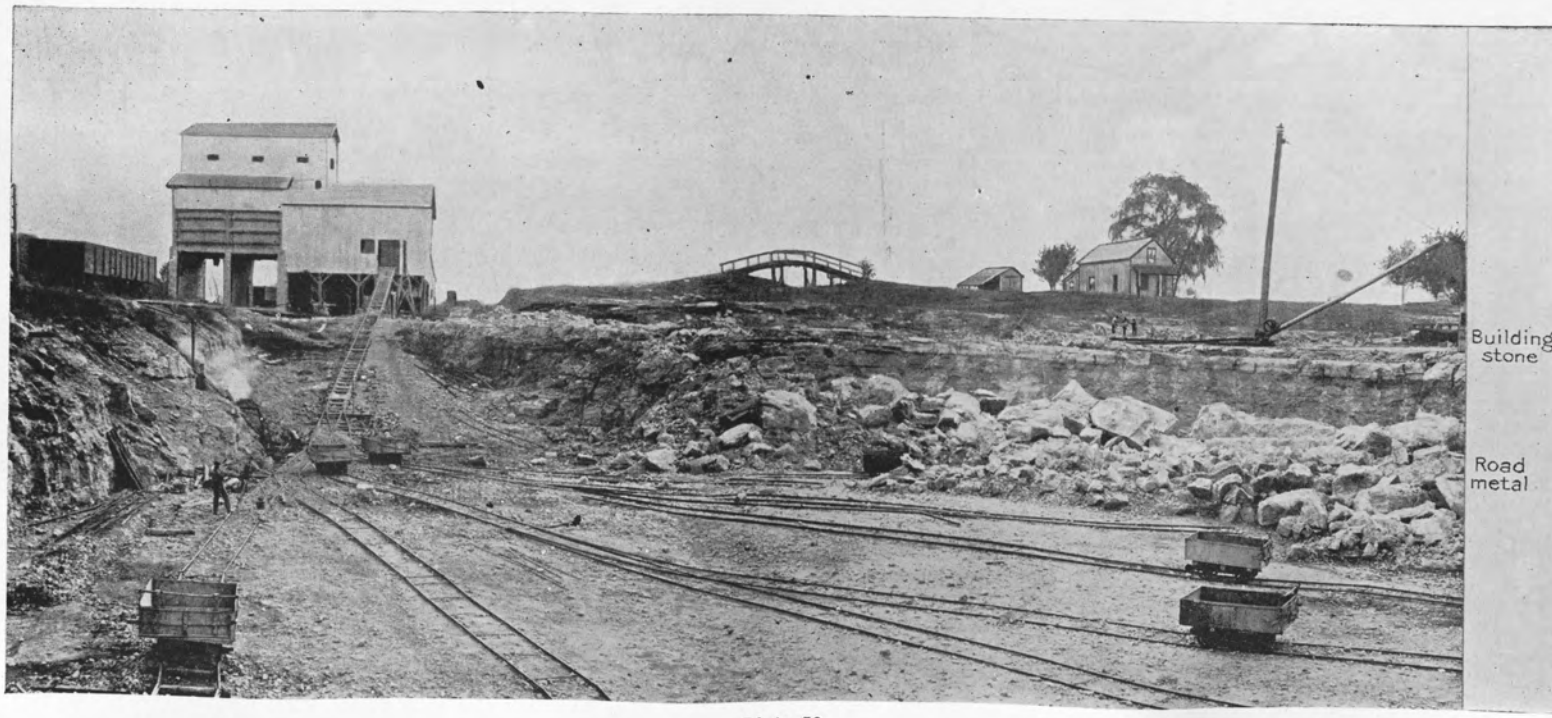


Plate 59.
Panoramic view in the quarry at Tucker.

With the exception of the cherty layers, this limestone is all utilized for building stone or curbstone. The rock works readily into blocks of desired sizes and is extensively used for foundations, for dwellings, retaining walls, fences and curbing. These uses are illustrated in Plate 58. It is used to a less extent for superstructures, and a number of churches in Louisville are constructed of it. Its uniformly soft, buffish to bluish-gray tints, make a very pleasing exterior appearance. A good example is the Presbyterian Church at Broadway and Second Avenue, Louisville.

Tests of samples of the Louisville limestone collected by the writer or his associates were made by the U. S. Bureau of Standards with the results given beyond. (See road metal tests and physical tests on a succeeding page.)

The Laurel dolomite also carries a fine grade of building stone in the upper half. The following section shows the general character of the bedding which is also illustrated by Plates 25 and 59.

Section of Laurel Dolomite at Tucker Quarry, Tucker.

	Ft.	In.
Laurel dolomite:		
12. Thin, weathered layers	2	
11. 9-inch ledge. Analysis G-3635		10
10. 9-inch ledge. Analysis G-3636		11
9. 8-inch ledge. Analysis G-3637		8
8. 11-inch ledge. Analysis G-3638	1	3
7. 14-inch ledge. Analysis G-3639	1	2
6. 5-inch ledge		5
5. 18-inch ledge. Analysis G-3640	1	6
4. Upper bed of road metal. Analysis G-3641	2	9
3. Road metal ledges, bedding indistinct. Analysis G-3642	16	0
2. Even grained bed quarried with road metal. Analysis G-3643	1	6
Osgood formation:		
1. Shale, upper, of Osgood.		
	29	0

The even-layered, upper part of the section, Nos. 5 to 11 inclusive, yields building stone of fine quality and ow-

ing to the bedding can be easily quarried and reduced to building blocks of any desirable dimensions. These layers are of fine, even grain and of uniform, rather light-gray color, tending to change to buff on exposure to the weather. In this region it has not been so long used for building as the Louisville limestone, and no examples of its use can be cited.

Samples of this rock tested by the Bureau of Standards gave the following results: (See road metal tests on a succeeding page):

Rock from the Saluda limestone has been used on a small scale for heavy masonry. It is a thick-bedded, soft, free-working rock of fine, even grain, and uniformly bluish-gray color in the fresh condition, but becoming banded on weathering with brown, yellowish, and pinkish colors. It also becomes shaly on long-continued weathering due to the presence of laminations not visible in the fresh conditions. These features are illustrated in Plates 17 and 19. This bed makes up the main body of the Saluda limestone, and is about 30 feet thick. On account of its rather soft and free working qualities and of its thick layers, large dimension stone for heavy masonry can be easily obtained from it. Owing to its thin lamination, however, care must be exercised to lay the stone with the edges to the weather as it lies naturally in the earth. The abutments of the bridge on the Louisville and Nashville Railroad ½ mile northwest of Eastwood, represent the only utilization of this rock in construction noted by the author. At this place the rock showed no sign of flaking or crumbling, although the abutments must have been built a good many years ago. The courthouse at Louisville is said to be built of rock obtained from the same formation at Madison, Indiana. Considerable disintegration is reported and the building has been protected with a coat of stucco. This rock is also in use for riprap at the locks of the Louisville canal. Samples of the Saluda stone were also tested by the Bureau of Standards with results shown below. (See road metal and physical tests on a succeeding page.)

The thin limestone layers in the Liberty and Arnheim formations have a limited local use for walls, chimneys, fences, etc. The thick-bedded, argillaceous lime-

stone of the Waynesville might be suitable for building purposes also, although judging from appearances, the bedding is not very even nor does it break across the bedding with a clean fracture. It appears to be affected with irregular seams and joints (see Plate 13).

The Kenwood and Holtsclaw sandstones should afford building stone for a limited local use.

Report of Physical Tests on Four Samples of Building Stone From Shanks' Quarries, Louisville, Ky. Submitted by U. S. Geological Survey. Bureau of Standards, Washington, D. C. S. W. Stratton, Director. September 1, 1915.

Samples Nos. 2,993, 2,994 and 2,995 are from the Louisville limestone from Shanks' quarry in the eastern part of Louisville. Sample No. 2,996 is from the Saluda limestone from quarry one mile west of Seatonsville.

Transverse Tests.

Lab. No.	Piece No.	Modulus of Rupture	Average
2993	1	2980	
2993	2	2739	2737
2993	3	2492	
2994	1	2441	
2994	2	2576	2566
2994	3	2680	
2995	1	1847	
2995	2	2138	2020
2995	3	2075	
2996	1	1978	
2996	2	2243	2104
2996	3	2090	

Remarks: All pieces broken perpendicular to the bed.

Percentage of Absorption, True Specifie Gravity, Apparent Specific Gravity and Porosity.

Lab. No.	Piece No.	Percentage of Absorption	Average	Apparent Specific Gravity	Average	True Specific Gravity	Average	Porosity (Percentage of Pore Space.)
2993	1	2.452		2.611		2.796		
	2	2.142	2.465	2.633	2.613	2.804	2.799	6.65
	3	2.800		2.594		2.796		
2994	1	1.765		2.640		2.800		
	2	2.147	1.830	2.620	2.633	2.797	2.792	5.70
	3	1.579		2.638		2.779		
2995	1	2.676		2.559		2.856		
	2	2.499	2.540	2.570	2.561	2.854	2.853	10.24
	3	2.444		2.553		2.850		
2996	1	2.955		2.564		2.858		
	2	3.168	2.891	2.588	2.576	2.850	2.855	9.77
	3	2.551		2.576		2.856		

Comparative and Compressive Strength of Original and Frozen Sampl es and Change of Weight on Freezing.

		Compressive strength (lb. square inch.)						
Lab. No.	Piece No.	Original Samples	Average	Frozen Samples	Average	Percentage Loss	Percentage Gain	Percentage Change in Weight (gain)
2993	1	13722		14791				0.67
	2	16885	15303	14373	14582	4.70	....	0.72
	3	16152		12873				0.81
	4	16339	16246	....	12873	20.77	....	....
2994	1	13874		15815				....
	2	13147	13510	13425	14620	....	8.22	0.28
	3	13138		15394				0.29
	4	15984	14561	17151	16272	....	11.77	0.31
2995	1	11201		11718				0.31
	2	11837	11519	11869	11794	....	2.38	0.08
	3	11313		12291				0.09
	4	13298	12306	12392	12342	....	0.30	0.14
2996	1	15498		11709				0.31
	2	13368	14433	12284	11997	16.85	....	0.33
	3	15650		13342				0.13
	4	15594	15622	....	13342	14.59	....	0.08

Remarks: Samples No. 1 and No. 2 were tested on bed and No. 3 and No. 4 on edge in every case.

Comparative Compressive Strength of Wet and Dry Samples.

Lab. No.	Piece No.	Compressive Strength of Dry Stone. lb. sq. inch.	Average	Compressive Strength of Wet Stone. lb. sq. inch.	Average	Comparative Strength of Dry and Wet Stone. Per cent. Loss	Gain	Description.
2993	1	13722	15303	15104	13170	13.93	......	Gray with occasional hard quartz like pockets, some pyrites.
	2	16885		11236				
	3	16152	16246	12006	12006	26.11	......	
	4	16339		......				
2994	1	13874	13510	13596	13814	......	2.25	Gray with hard quartz like pockets, some pyrites.
	2	13147		14033				
	3	13138	14561	14517	12968	10.94	......	
	4	15984		11418				
2995	1	11201	11519	8493	8398	27.10	......	Yellowish to greenish gray fine grained uniform texture.
	2	11837		8304				
	3	11313	12306	10921	10518	14.51	......	
	4	13298		10116				
2996	1	15498	14433	8628	9210	36.22	......	Marked: Saluda. Yellowish to greenish gray fine grained uniform texture.
	1	13368		9793				
	3	15650	15622	10660	11088	29.95	......	
	4	15594		11516				

Remarks: In each case samples No. 1 and No. 2 were tested on bed and No. 3 and No. 4 on edge.

ROAD METAL.—Crushed rock for road metal is extensively obtained from the Louisville limestone and Laurel dolomite and to a less extent from the Saluda and Waynesville limestones. Besides the shipping quarry at Tucker and the permanent quarries at Louisville, local and temporary quarries are opened in any of these beds near points where the metal is applied to the roads. An abundant supply can thus usually be had at easily accessible points in the larger part of the county. It is to this circumstance that the county's excellent system of metaled roads is partly due. The quality of the rock as road metal from the various limestone formations is given in the following statements of the results of tests made by the United States Office of Public Roads on samples collected under the writer's supervision:

Road Metal Test Made by the United States Department of Agriculture, Office of Public Roads, Washington, D. C.

No. 8334. No. 2997. Laurel dolomite from Tucker Quarry, Tucker.

Specific gravity	2.65	
Weight per cubic foot	165	pounds.
Water absorbed per cubic foot	1.87	pounds.
Per cent. of wear	5.12	
French coefficient of wear	7.8	
Hardness	16.2	
Toughness	11	
Cementing value	Good.	

No. 8335. No. 2998. Louisville limestone from "Shanks Quarry," Louisville.

Specific gravity	2.65	
Weight per cubic foot	165	pounds.
Water absorbed per cubic foot	3.8	pounds.
Per cent. of wear	5.0	
French coefficient of wear	8.0	
Hardness	8.33	
Toughness	6	
Cementing value	Fair.	

No. 8336. No. 2999. Sandy Saluda limestone from quarry 1 mile west of Seatonsville.

- Specific gravity 2.70
- Weight per cubic foot .... 168 pounds.
- Water absorbed per cubic foot .... 0.88 pounds.
- Percent. of wear 4.7
- French coefficient of wear 8.5
- Hardness 13.5
- Toughness 7
- Cementing value .... Fair.

No. 8337. No. 3000. Hitz limestone from local road metal quarry on ridge about 2 miles north northeast of Boston.

- Specific gravity 2.70
- Weight per cubic foot .... 168 pounds.
- Water absorbed per cubic foot .... 1.08 pounds.
- Per cent. of wear 4.1
- French coefficient of wear 9.8
- Hardness 15.2
- Toughness 7
- Cementing value .... Good.

No. 8338. No. 3001. Waynesville limestone from local road metal quarry on Brush run 2¼ miles east of Seatonsville.

- Specific gravity 2.70
- Weight per cubic foot .... 168 pounds.
- Water absorbed per cubic foot .... 1.21 pounds.
- Per cent. of wear 5.3
- French coefficient of wear 7.5
- Hardness 13.2
- Toughness 7
- Cementing value .... Fair.

According to road metal standards, the French coefficient of wear of samples 8334 and 8388 is low, and of the remaining samples, medium. The hardness of samples 8334 and 8837 is medium, of the others low.

These tests seem to show that the Hitz limestone makes the best grade of road metal in the county.

The Following Table Gives Maximum and Minimum Results of 1032 Samples of Limestones Tested by the Office of Public Roads, United States Department of Agriculture.

No. of Samples	Material	Specific Gravity			Weight, Pounds Per Cubic Foot			Water Absorbed, Pounds Per Cubic Foot		Per Cent of Wear		French* Coefficient of Wear		Hardness		Toughness		Cementing Value	
		Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1032	Limestone	2.85	2.00	2.67	178	125	167	13.22	0.02	34.2	1.8	21.7	1.2	19.2	0.0	25.	2.	500	8

*See explanation of results.

EXPLANATION OF RESULTS GIVEN IN TABLE.

Resistance to Wear.

Resistance to wear is a special property in a rock, and although it depends to a large extent upon both the hardness and the toughness of the rock it is not an absolute function of these qualities.

The per cent. of wear in the table refers to the dust and detritus below one-sixteenth of an inch in size worn off in the abrasion test. The test is made in the following manner: Eleven pounds (5 kg.) of broken rock between 1¼ and 2½ inches in size, 50 pieces, if possible, are placed in a cast-iron cylinder mounted diagonally on a shaft and slowly revolved 10,000 times.

The French coefficient of wear is obtained by dividing 40 by the per cent. of wear. Thus a rock showing 4 per cent. of wear has a French coefficient of wear of 10. The French engineers, who were the first to undertake road-material tests, adopted this method of recording results. They found that their best-wearing rocks gave a coefficient equal to about 20. The number 20 was therefore adopted as a standard of excellence. In interpreting the results of this test a coefficient of wear below 8 is called low; from 8 to 13, medium; from 14 to 20, high; and above 20, very high. Rocks of very high resistance to wear are suited only for heavy traffic.

Hardness.

By hardness is meant the resistance of a rock to the grinding action of an abrasive agent like sand, and it is tested as follows:

A core 1 inch in diameter, cut from the solid rock, is faced off and subjected to the grinding action of sand fed upon a revolving steel disk against which the test piece is held with a standard pressure. When the disk has made 1,000 revolutions the loss in weight of the sample is determined. In order to report these results on a definite scale which will be convenient the method has been adopted of subtracting one-third of the resulting loss in weight in grams from 20. Thus a rock losing 6 grams has a hardness of 20—6/3, or 18. Experience has shown this to be the most convenient scale for reporting results. The results of this test are interpreted as follows: Below 14, rocks are called soft; from 14 to 17, medium; above 17, hard.

Toughness.

By toughness is meant the resistance a rock offers to fracture under impact; such, for instance, as the striking blow given by a shod horse. This property is tested in a specially designed machine built on the pile-driver principle, by which a standard weight is dropped upon a specially prepared test piece until it breaks. The height in centimeters of the blow which causes the rupture of the test piece is used to represent the toughness of the specimen. Results of this test are interpreted so that those rocks which run below 13 are called low; from 13 to 19, medium; and above 19, high.

Cementing Value.

By cementing value is meant the binding power of the road material. Some rock dusts possess the quality of packing to a smooth, impervious mass of considerable tenacity, while others entirely lack this quality. Cementing value should not be confused with the property possessed by Portland cement, which causes it to set into a hard, stone-like mass when mixed with water. The cementation test is made as follows:

The rock sample is ground in an iron ball mill with sufficient water to form a stiff, fine-grained paste. From the paste small briquettes 1 inch (25 mm.) in diameter and 1 inch high are molded under pressure. After thoroughly drying the briquettes are tested under the impact of a small hammer which strikes a series of standard blows. The number of blows required to destroy the briquette is taken as a measure of the cementing value of the dust. Some rock dusts, when thoroughly dried into compact masses, immediately slake or disintegrate when immersed in water. It is considered that the tendency to act in this way is not a desirable characteristic of a road material, as it would lead to muddy conditions on the road surface after rains. The test is interpreted so that cementing values below 10 are called low; from 10 to 25, fair; from 26 to 75, good; from 76 to 100, very good; and above 100, excellent.

Weight Per Cubic Foot.

The weight per cubic foot refers to the weight of the material in the form of a solid and not as broken stone.

LIME.—Very little limestone suitable for lime manufacture exists in Jefferson County. For lime (calcium oxide) which is obtained from limestone by heating to drive off the carbon dioxide gas, a limestone nearly free from silica, alumina, and from iron oxide is required, since only a product containing less than 5 per cent. of these impurities is considered as lime by the National Lime Manufacturers' Association. A glance at the Table of Analyses will show that only the Jeffersonville limestone, analysis G-3,612; the Brassfield limestone, analyses 3,650 and 3,662, and the lower cross bedded limestone in the Arnheim formation, analysis 3,645, are low enough in the specified impurities to burn to lime of the required degree of purity. Of these limestone strata, the Brassfield is too thin to be considered as a source of lime from a commercial standpoint. The bed in the Arnheim is, so far as observed, generally only 4 to 5 feet thick. However, on the run north from Oak Ridge school, one-eighth mile south of its junction with Cane Run, a bed in the Arnheim, supposed to be the same as that in Brush Run from which the sample of analysis 3,645 was taken, is 13 feet thick. Possibly this bed could be exploited profitably for lime burning where not under too deep cover. Its suitability for the purpose would depend also upon its having the same purity of composition elsewhere as on Brush Run east of Seatonsville where sampled.

The Jeffersonville limestone is 20 feet thick and is arealy extensive so that if it maintains the purity shown by analysis G-3,612 through its full thickness and throughout its extent it is a possible source of lime worthy of consideration and investigation. It lies near the top of the hills and spurs and unless the overburden of soil is greater than appears, could be economically quarried. The quantity available is sufficient to warrant exploitation if its supposed suitability should be verified.

PORTLAND CEMENT.—The Jeffersonville limestone is of a composition suitable for Portland cement manufacture and is the only such limestone in the county of sufficient extent and thickness to be considered in that connection. The Louisville limestone and Laurel dolomite contain too great a proportion of magnesium carbonate for such use, which does not admit a magnesium carbonate content exceeding 5 per cent. for the best quality of cement.

All the limestone used for this purpose in the county is obtained from points west of Jefferson County. The subject of cement will be treated in connection with the description of clay, since that is the only raw material of Portland cement mined in the county.

NATURAL CEMENT.—As well known, the Silver Creek (hydraulic) limestone (cement bed) has been in former years extensively utilized in the manufacture of natural cement, or hydraulic lime, in Indiana, and to a small extent in Kentucky at Louisville. The composition of this rock is such that on calcination and pulverization, it has the property of "setting," or in other words behaves as a cement. The range in composition of this rock is shown in the two analyses below:

Analyses of Silver Creek Limestone.*

	1	2
Calcium carbonate	54.31	51.95
Magnesium carbonate	16.90	32.97
Silica	18.33	9.69
Ferric oxide	1.67	1.95
Alumina	4.98	2.77
Lime, CaO	6.14	6.10
Magnesia MgO	6.33	6.11
Undetermined	1.19	0.36
	97.85	99.90

No. 1. Quarry of Ohio Valley mill.

No. 2. Quarry of Black Diamond mill, both in Indiana, 6 to 7 miles northeast of Louisville.

The Silver Creek limestone, of unknown thickness but probably not over 10 feet, exists beneath the city of Louisville in Kentucky, and in former years was utilized to some extent as a source of natural cement by a cement mill located at Louisville. The rock was quarried at the foot of 14th Street near the Pennsylvania Railroad bridge where the bottom of the Silver Creek limestone is about at low water level. The formation thins out eastward and on Payne Street near Sturgus is only 1½ to 2 feet thick.

*Extracted from the 25th Annual Report of the Ind. Geol. & Nat. Res., pp. 380-381.

Owing to the small thickness and limited extent of this formation in the county, to the unfavorable conditions of quarrying (exploitation on a large scale would involve mining), and to the further fact that natural cement is largely passing out of use, the Silver Creek limestone can not be considered a mineral resource of importance in this county.

FERTILIZER.—Any of the limestone formations mentioned above as adapted to the manufacture of lime would also furnish agricultural lime either as lime or ground limestone, those (like the Jeffersonville limestone) showing the highest percentage of calcium carbonate in the table of analyses being the most suitable.

QUARRYING CONDITIONS.—The quarrying conditions of the limestone strata suitable for use are excellent. The strata are nearly flat or dip at a very low angle and they are the surface formations over large areas where they are accessible with but little stripping. Large bodies of the Louisville limestone are thus easily accessible in the bluffs of Beargrass Creek and Ohio River east and northeast of Louisville and likewise in close proximity to the city market so that transportation costs are light. Conditions are extremely favorable for attacking the Louisville limestone along the broad belt of gently westward dip on the slope east of Fern Creek (stream) as shown by the structure contours on the geologic map and by the profile sections. Transportation could be cheaply provided by a railroad spur from the Southern Railroad. The low dip would make quarries self draining. Conditions are likewise favorable in large areas of Laurel dolomite, as in the vicinity of Tucker and Avoca. The Jeffersonville limestone is also easily accessible over large areas as is evident on an inspection of the map. Favorable sites for quarrying the limestones of the Richmond Group can be found at many points in the Floyds Fork drainage basin. The Saluda limestone forms the surface over extensive areas west of Floyds Fork between the Louisville & Nashville and the Southern Railroads, where its exploitation would involve but little stripping. The Waynesville and Arnheim limestones, which might be utilized to a considerable extent as road metal, and some beds of the latter possibly for ground limestone for fertilizer, can be advantageously operated at numerous points on the spurs or along the streams tributary to Floyds Fork on the east.

DEVELOPMENT.—The principal development of the limestone industry has been on Beargrass Creek, in the eastern part of Louisville, where are several quarries in the Louisville limestone furnishing building stone, curbstone, and crushed stone for concrete and macadam, to the city and adjoining parts of the county. There is also a large quarry at Callahans and another at Florida Heights. The only operation in the Laurel on a commercial scale is at Tucker where is located the best equipped quarry in the county, engaged in the production of building stone and crushed stone. (See Plate 25.) In addition to these permanent quarrying operations there are usually in operation a number of temporary ones supplying road metal near points where the material is applied.

PRICES AND TOTAL PRODUCTION.—The prices and amounts of the limestone products of Jefferson County, Kentucky, for the year 1914, furnished by the Division of Mineral Resources of the United States Geological Survey, are given in the following tables.

The various classes of limestone products are sold in various units and at varying prices as stated.

Prices of Limestone Products.

Building stone. $1.50 per cubic yard. $1.10 to $3.00 per perch. $2.00 per load. $1.00 per ton.	Riprap. $1.00 per cubic yard. Agricultural lime. $1.50 per cubic yard.
Crushed stone. 40 to 70 cents per short ton.	Flux. $1.10 per long ton.
Paving stone. 25 cents per square foot.	Curbing. $2.00 per perch. 25 to 33 cents per linear foot.
Rubble. 40 cents per load. $2.50 per perch.	

The Total Amount and Gross Value of the Various Classes of Limestone Products for the Year 1914 are as Follows:

	Quantity.	Value.
Building stone (rough)	7,430 perch	$9,492
*Paving stone	150 square feet	40
Curbing	21,400 linear feet	7,132
Rubble	1,125 perch	2,540
*Riprap	200 cu. yd.	200
Crushed stone	144,164 short tons	80,759
*Flux	1,700 long tons	1,870
*Agricultural lime	248 short tons	328
Total		$102,361

*One operator.

CLAY AND SHALE.

BUILDING BRICK.—Clay and shale suitable for common and press brick and possibly for paving brick exist in Jefferson County in inexhaustible quantities. The clay is both sedimentary and residual.

The sedimentary clay is associated with the glacial outwash deposits on the broad terrace bordering the river on the southeast upon which Louisville is built. This clay is utilized for dry pressed brick by the Louisville Brick Company at its plant at 38th Street and Rudd Avenue, Louisville. The deposit lies on an intermediate terrace about 25 feet above low water and has been worked to a depth of about 10 feet over an area of several acres. It is reported 12 to 30 feet thick and its areal extent is unknown, but probably great.

The clay is loosened to a depth of 1 to 2 inches and gathered by wheel scrapers and conveyed to storage sheds whence it passes to dry grinders, thence to slanting screens of piano wire, the material passing the screen being of the fineness of flour. This goes to the bins, from which it passes to the dry presses, of which there are two of 20,000 daily capacity each. The clay retains enough water to amount to 1 pound for each brick as it comes from the press.

The bricks are in the kilns 17 days, including 6 days cooling. The fuel used is coal and coke—the latter during cooling. It is necessary to heat up and cool off very slowly to avoid checking. The total shrinkage in burning is ½ to ¾ inch in length of brick as pressed. The brick are of a pleasing red tone except those from the top of the kiln which are paler, being somewhat under burned. The strength is adequate to all ordinary uses of building brick. The kilns are 5 rectangular up draft, 2 of 500,000 and 3 of 350,000 capacity, and 1 round, down draft, of 70,000 capacity. The total capacity of the plant is 40,000 daily. The bricks are largely marketed in Louisville, the price of selects being $12.000 per 1,000.

Sedimentary clay of the type just described is probably of wide distribution in the glacial outwash terrace. It is extensively used at Kosmosdale in Portland cement making. The deposit at Kosmosdale is described under the head of Portland cement.

The residual clay utilized is heavy red clay, resulting from the decomposition of the Jeffersonville limestone in the vicinity of Whitner. This forms a mantle up to 10 feet thick, a section of which as measured at the pit of the Southern Brick and Tile Company is as follows:

Section of the Residual Clay From the Jeffersonville Limestone. Sections Measured at Points 200 Feet Apart.

No. 1.	Ft.	In.
3. Earth brown	1	8
2. Clay, tawny, stiff	2	6
1. Clay, tawny, stiff, mottled with red	1	
	5	2

No. 2.	Ft.	In.
3. Earth, brown	1	
*2. Clay, tawny, stiff	2	
*1. Clay, red	4	
	7	

The chemical composition of this clay is exhibited by the analysis No. G.3,665 of the table.

At the plant of the Southern Brick and Tile Co. the clay is loaded in cars by hand and hauled by mules to an incline. It is put through a screw disintegrator, revolving crusher, pug mill, and Potts automatic, soft mud, brick machine. The bricks are loaded on trucks on which they go to the dryer through which they pass in 3 days, the temperature increasing from 100° at beginning to 180° at end of drying period. The dryer is a building in which are a series of slightly inclined tracks so that the trucks move by gravity from the entrance to the point of exit opposite the kilns. The burning period is 11 days beginning with wood and coke and finishing with coal. The total shrinkage in drying and burning is about 1 inch in 9 inches, the length of the brick as moulded. There is very little cracking. There are 4 rectangular updraft kilns of 400,000 capacity each, the daily capacity being 35,000. The bricks are of good density and have a rich red color and are suitable for all purposes of a building brick either for interior or exterior use.

*Sample Analysis G-3665.

This same clay is used by the East End Brick Company located at Spring and Arlington Streets, Louisville, with a capacity of 25,000 daily.

The New Providence shale is now being utilized for common brick by the Coral Ridge Clay Products Company at their plant at Coral Ridge. A thickness of about 25 feet is being quarried in the lower half of the formation. In addition to the shale the overburden consisting of wash, earth, sand, etc., is used, making up about 1/3 of the raw material. The composition of the shale is shown by analyses Nos. G-3,654 and 3,655 of the table.

The works are located at the west base of the Norton hills and the shale pit is opened in the point of a low spur convenient to the plant and to the Louisville and Nashville Railroad. The raw material is obtained by steam-shovel and transferred by cars on incline to storage shed. Thence it passes by belt conveyors to dry pans, the larger chunks of sandstone and the larger nodules of iron carbonate being hand picked from the conveyors. From dry pans the material goes to piano wire screens and thence to mixer, receiving water to reduce to proper consistency; thence to automatic 24-wire brick machine. The bricks then go to a dryer and thence to the kilns where they remain 18 to 20 days. The kilns are all downdraft, 5 rectangular of 150,000, and 5 round of 65,000 capacity. The temperature is registered by electric pyrometers for various parts of the kiln so that complete control can be maintained at all times. As a result the bricks are very successfully burned and uniform in all parts of the kiln and there is no loss due to over or under burning. The bricks are dense, apparently strong, and of a pale red color. The bricks have one defect which is the formation of a white scum or film on the surface due to the efflorescence of soluble sulphates, such as sodium or potassium sulphate. This results from the considerable proportion of sodium and potassium carbonates in the shale as revealed in the analyses. This defect can be overcome by the use of a small quantity of barium carbonate by which the soluble sodium and potassium sulphates are converted into insoluble barium sulphate. With the exception of this feature of the shale, which only injures the brick for exterior use, the New Providence shale seems to be an excellent raw material for brick. It is suggested that its

use alone excluding the surficial material might result in a smoother and tougher brick.

The Coral Ridge plant is ideally located as to exploitation of the raw material and transportation facilities and is in every respect a well equipped plant. A general view is shown in the photograph, Plate 60.

PAVING BRICK.—No paving bricks are made in the vicinity of Louisville, but there should be a good market for them. This suggests the inquiry whether a raw material suitable for their manufacture exists in Jefferson County. It seems quite certain that at least the upper half of the Rosewood shale, so far as can be determined from the analyses Nos. G-3,657-58-59-60, is suited for paving brick. The limit of composition of shale for paving brick as given by Wheeler* is as follows:

Analyses of Clay Used for Making Paving Brick.

	Minimum.	Maximum.	Average.
Silica (SiO_2)	49.00	75.00	56.00
Alumina (Al_2O_3)	11.00	25.00	22.50
Ferric Oxide (Fe_2O_3)	2.00	9.00	6.70
Lime (CaO)	0.20	3.50	1.20
Magnesia (MgO)	0.10	3.00	1.40
Alkalies (Na_2O, K_2O)	1.00	5.50	3.70
Ignition	3.00	15.00	7.00

The four analyses of the Rosewood shale in the table, Nos. G3,657-60, show that its composition falls within the limits given in Wheeler's table. Since there are limitless quantities of this shale easily available close to railroad lines, as along the Louisville, Henderson and St. Louis Railroad between Kathryn Station and the north side of Moremens Hill, it seems that the manufacture of paving brick might be undertaken with reasonable prospects of success and profit.

PORTLAND CEMENT MANUFACTURE.—Portland cement is a product of which the principal constituents are silicates of lime, or calcium silicates, which are combinations of silica (quartz), with calcium oxide, or lime; and calcium aluminates which are combinations of calcium and alumina. These cements are produced from a mixture of

*Wheeler, Vitrified Paving Brick. Quoted from Bull. No. 15, Wis. Geol. Survey, p. 39, 1906.

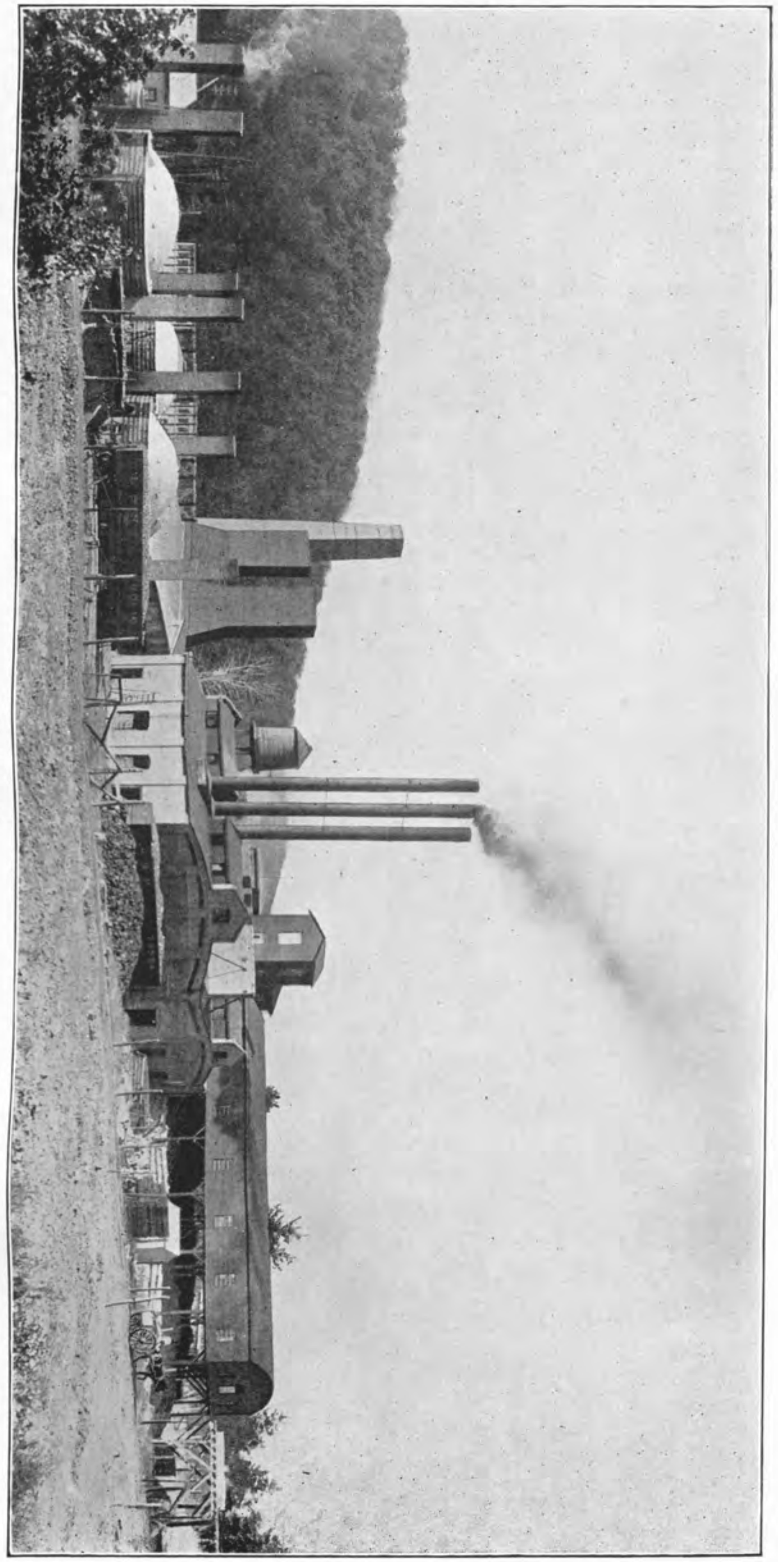


Plate 60.
View of brick works of Coral Ridge Clay Products Company at Coral Ridge.

clay and limestone or of shale and limestone. The clay or shale supplies the silica and alumina and the limestone supplies the calcium oxide.

Clay or shale is composed of silica, alumina, iron oxide and various other minor constituents as may be seen in the table of analyses. It has been found by experience that a clay or shale in which the ratio of silica to alumina and iron oxide is about 3 of silica to 1 of the sum of the alumina and iron oxide gives the best results, considered from the standpoint of quality and economy of production.

In the cement mixture it is suggested that the alumina and iron oxide act as a flux* to lower the temperature at which the combination of the calcium and silica will take place. If there is not sufficient of the fluxing ingredients the temperature of combination is too high to be attained with economy; if there is an excess of the fluxing ingredients beyond the ratio indicated above, the strength of the cement is reduced below the requirements.

It is assumed in the above discussion that the limestone used is of a high degree of purity. If it should contain much silica, etc., the proportions of the ingredients in the clay or shale would be different from those required by a pure limestone.

Also, it may be assumed if other fluxing ingredients are present in clay or shale, that the proportions of alumina or iron oxide might be less, the main requirement being apparently that the ratio of fluxing ingredients to silica be as 1 to 3. This last consideration is introduced here for its bearing on the suitability of the Carboniferous shales of the county for cement manufacture.

Clay is the only raw material of cement produced in Jefferson County. This is used by the Kosmos Portland Cement Company in their plant at Kosmosdale and is obtained from the surface of the glacial outwash terrace near the plant.

The clay is of sedimentary origin and may belong to the glacial outwash or may have been deposited at a later date upon the outwash surface under swampy conditions similar to those originally existing in the low area between the Knobs and the Preston Street turnpike.

*Eckel, E. C. U. S. Geol. Survey Bull. 243, p. 24.

In such a case the clay was derived from the decomposing shale outcropping on the knobs immediately east of the terrace. The thickness of the clay varies from 1 to 7 feet. At the bottom scattered quartz gravel, sand, or sandy clay too siliceous for cement use is encountered.

The composition of the clay is given in analysis No. G-3,661, and also in the following analyses kindly furnished by Mr. Stugard, assistant superintendent and chief chemist of the cement company.

Partial Analyses of Clay at Various Depths in Clay Pit of Kosmos Portland Cement Company at Kosmosdale.

	Surface to 2 ft.	2′ to 4′	4′ to 6′	6′ to 8′	8′ to 10′
Silica	62.40	64.35	65.55	67.75	70.30
Alumina and iron oxide	24.15	25.80	22.80	22.30	21.35

These analyses show a constant increase of silica relative to alumina and iron oxide with increase of depth. At the bottom of the pit the silica is in excess of the required ratio. The extent and quality of clay deposits like that at Kosmosdale is not known, but presumably large areas of such exist on the glacial outwash terrace.

The matter of using shale from the New Providence or Rosewood shales has been considered to some extent by the Kosmos Company. So far as the analyses indicate the New Providence shale contains too high a proportion of fluxing ingredients, the sum of alumina, iron oxide, potash and soda averaged from analyses G3,654 and 3,655 being 31.26 per cent., while the average silica is 60.42 per cent. The fluxing ingredients are therefore, if the analyses are representative, a little more than half the silica, a proportion that apparently excludes the New Providence shale without further addition of silica as an ingredient in Portland cement mixture. This shale might, however, be used to mix with the more siliceous clay at the bottom of the present workings and so make available a large body of clay that can not be used alone. The magnesium carbonate in the New Providence is also very near the limit allowable in the cement mixture. The Rosewood shale makes a better showing. The four analyses from the upper half show an average of 25.70

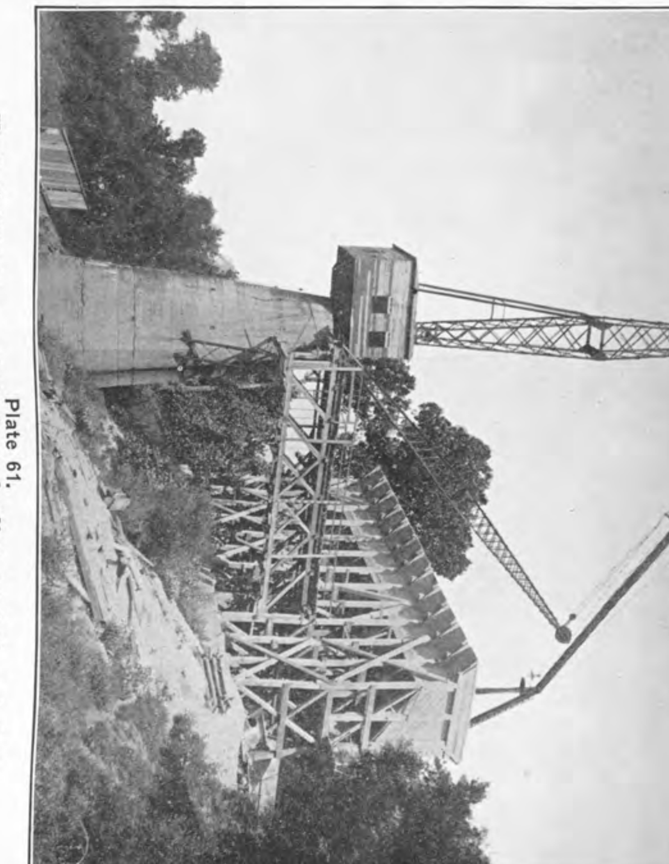


Plate 61.
View of limestone pockets for unloading crushed rock from quarry, Kosmosdale, Kentucky. Looking northeast from barge at the river side.

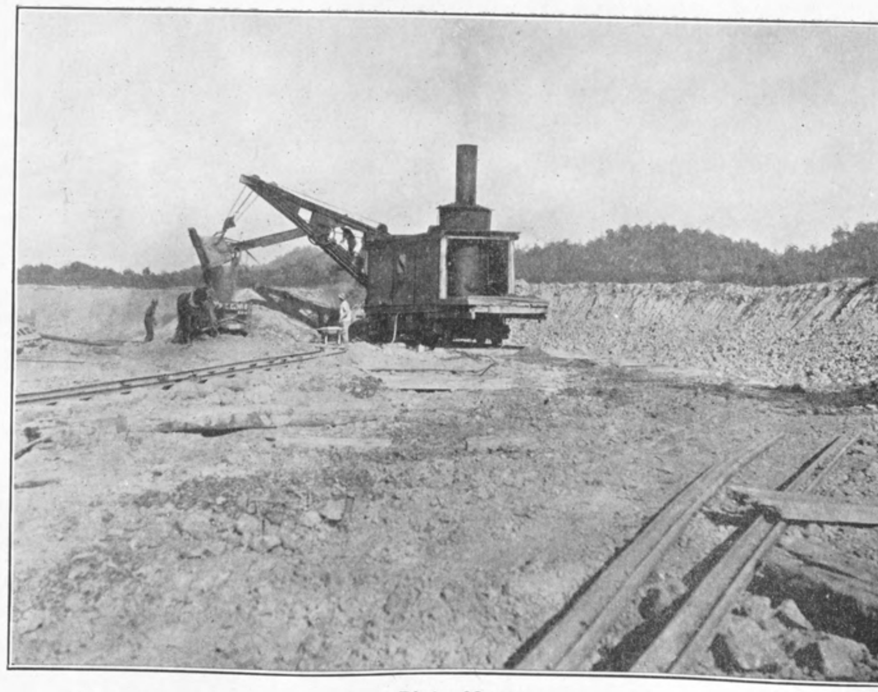


Plate 62.
View of the clay pit of the Kosmos Portland Cement Company, Kosmosdale, Kentucky. Looking northeast.

per cent. of fluxing ingredients and the average silica 66.93 per cent. Here, too, the proportion of fluxing ingredients is somewhat above the ideal ratio, the ratio of silica to flux being about 2½ to 1. It seems that this shale might be used, especially if the limestone used should run a little higher in silica on the average than the samples represented by the analyses below.

Both the New Providence and the Rosewood shales are easily accessible to the plant at Kosmosdale, the former in the vicinity of Hunters Trace and south to Waverly Hill and the latter in the bluffs directly east of the plant.

Owing to the lack of limestone in the county suitable for cement manufacture, the stone used by the Kosmosdale works is obtained from the Upper Mississippian limestone near Brandenburg, Kentucky, about 30 miles down the river from Kosmosdale. The rock of the quarry face, which is about 100 feet high, is of high purity as shown by the following analyses:

	1	2
Loss on ignition, water, carbon dioxide, etc.	42.54	43.61
Lime (calcium oxide CaO)	52.80	55.30
Silica (SiO_2)	2.15	0.69
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	1.40	......
Iron oxide	......	0.27
Magnesia (MgO)	.80	.35

1. Analysis by F. Stugard, Chief Chemist of the Kosmos Company.
2. Analysis by Ky. Geol. Survey, hand specimen.

The only limestone in Jefferson County approaching this grade is the Jeffersonville, which has already been discussed.

Since the manufacture of Portland cement at Kosmosdale is one of the county's large industries, a brief description of the plant and process of manufacture is given below.

The limestone is crushed at the quarry by a Gates crusher reducing the stone to 6 inches diameter or less. It is then transported by barge up the river to Kosmosdale, where it is unloaded by crane and bucket into pockets, a view of which is shown in Plate 61. From the pockets the rock is conveyed about a quarter of a mile

by double track and endless rope haulage to storage sheds at the plant.

The clay is raised by steam shovel at the pit about $\frac{1}{4}$ mile east of the plant; see photograph, Plate 62. The clay is conveyed by double track and endless rope haulage to the storage shed (see photo Plate 63), in the rear of the plant.

Both limestone and shale pass through a Williams mill, the former being reduced to $\frac{7}{8}$ inches in diameter or smaller. Both then pass through driers. These are Standard Vulcan rotary driers 60 inches in diameter, 4 in number. The time in drier is three-quarters of an hour to an hour. From the driers the materials go to bins in the mixer building. The limestone is drawn from the bins in the mixer building into cars which are run onto scales beneath the dried clay hoppers from which clay is drawn into the cars on top of the limestone, the proportions being approximately 1 of clay to 4 of limestone. Thence the mixture goes to bins over the raw mills in which are 15 Fuller-Lehigh pulverizers. In passing through the pulverizers the mixture is reduced to a degree of fineness such that it will pass a 100 mesh sieve, and the ingredients are thoroughly intermixed, so that reaction between them takes place readily in the kilns and a very complete combination of silica and lime, etc., is obtained.

From the Fuller-Lehigh pulverizers the material goes to bins over the kilns into which it is fed. The kilns are huge, rotary, horizontal cylinders, of which there are four 7 feet in diameter and 80 feet long and two $8\frac{1}{2}$ feet in diameter and 125 feet long. The heat of the kilns is produced by incandescent powdered coal, fed by air blast. In the kilns the mixture under the action of heat combines to form clinker (the principal constituents of which are calcium silicates). From the kilns the clinker passes through rotating coolers and thence to storage bins.

The clinker, being a hard, cindery mass, next passes through grinding mills, of the Griffin type, of which the number is 12. From the Griffin mills the material passes to tube mills receiving on the way 2 per cent. plaster of

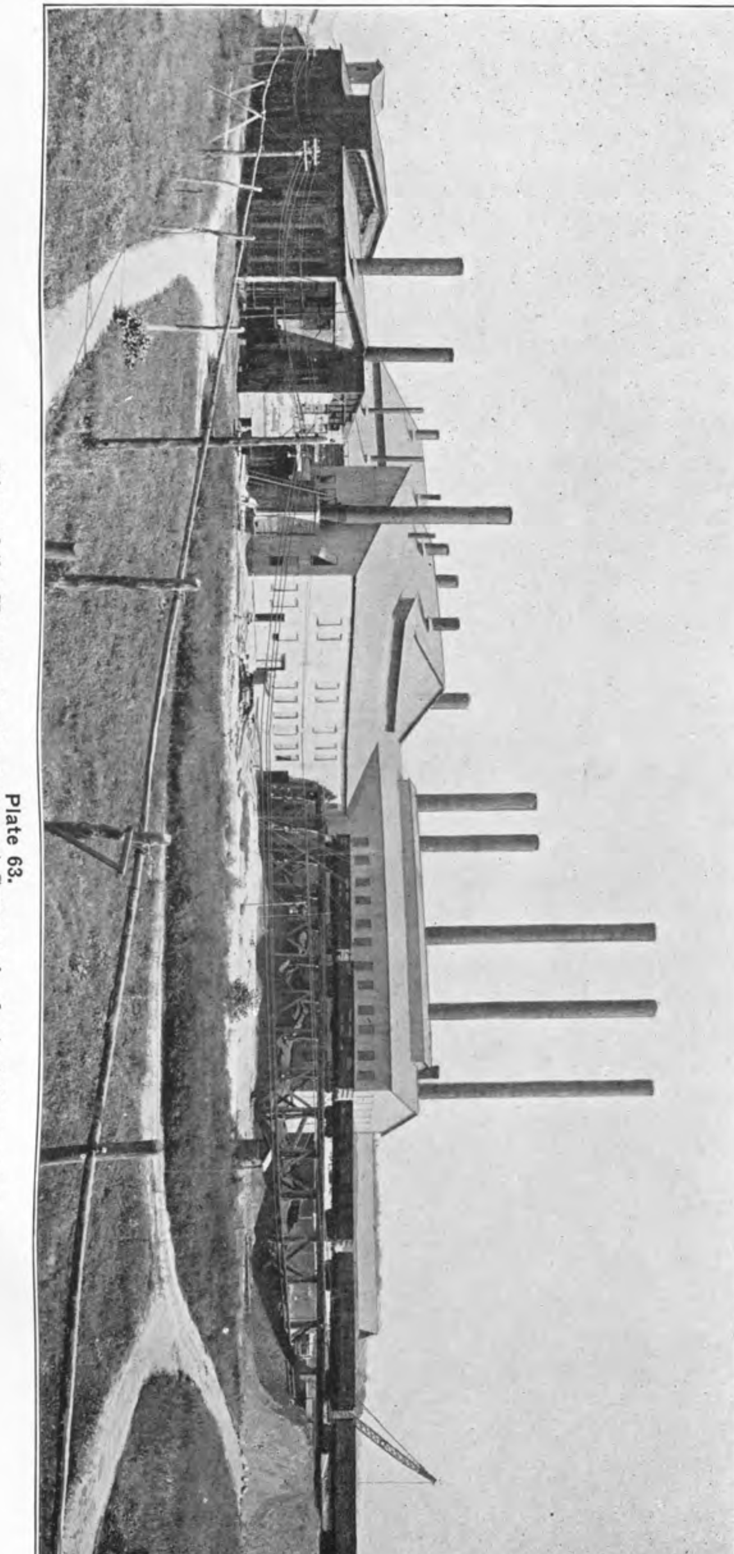


Plate 63.
View of the Kosmos Portland Cement Company's plant at Kosmosdale.

paris to regulate the setting of the cement. The tube mills are large, rotating, horizontal cylinders in which are flint pebbles. By the grinding action of these pebbles in the rotating tube mill the cement is reduced to its final condition of flour-like fineness. (See tests for fineness.)

From the tube mills the cement goes to storage bins and thence to bags automatically filled and weighed. The finished product as bagged is either loaded on cars for shipment or is placed in storage houses for future demand. The storage capacity is about 200,000 barrels.

A view of the Kosmosdale plant is shown in Plate 63.

The quality of the Kosmos cement is set forth in the following statements of the results of tests:

Analysis of Cement and Mixture of Raw Material. Furnished by F. Stugard, Chief Chemist of the Cement Company.

	Mixture	Cement
Silica (SiO_2)	15.10	23.10
Alumina (Al_2O_3)	3.90	6.45
Iron oxide (Fe_2O_3)	1.30	2.15
Lime (CaO)	42.25	62.50
Magnesia (MgO)	1.75	2.40
Sulphur trioxide (SO_3)	....	1.45
Loss on ignition (water and carbon dioxide, etc.)	35.10	1.10

Average Physical Tests of Finished Cement.

Fineness.

Per cent. passing 100 mesh screen	96
Per cent. passing 200 mesh screen	80

Set.

Initial 3 hours. Final 6 hours.

Specific Gravity

3.185

Tensile Strength.

	Neat.	3 to 1 sand.
24 hours	350 lbs.	
7 days	620 lbs.	220 lbs.
28 days	780 lbs.	380 lbs.

TESTS MADE FOR THE KENTUCKY GEOLOGICAL SURVEY OF SAMPLE FURNISHED BY F. STUGARD, CHIEF CHEMIST OF THE CEMENT COMPANY.

Fineness.

100 mesh sieve.		200 mesh sieve.	
No. 1	97.0	No. 1	85.0
No. 2	96.5	No. 2	84.5
No. 3	96.0	No. 3	84.0
Average	96.5	Average	84.5

Specific Gravity—Average 3.16

Time of Set.

Initial Set.		Final Set.	
No. 1	220 minutes	No. 1	340 minutes
No. 2	220 minutes	No. 2	345 minutes
No. 3	215 minutes	No. 3	335 minutes
No. 4	225 minutes	No. 4	330 minutes
No. 5	230 minutes	No. 5	325 minutes
No. 6	225 minutes	No. 6	330 minutes
Average	225 minutes	Average	334 minutes

Temperature { Room .... 72° F.
Water .... 70° F.

Normal consistency 20.6%

Soundness Pats.

Boiling water .... 5 hours .... O. K.
Cold water .... 7 days .... O. K.
Air .... 7 days .... O. K.

Tensile Strength.

Neat Cement.

24 hours.		7 days.		28 days.	
No. 1	400 lbs.	No. 1	664 lbs.	No. 1	800 lbs.
No. 2	395 lbs.	No. 2	610 lbs.	No. 2	797 lbs.
No. 3	397 lbs.	No. 3	635 lbs.	No. 3	790 lbs.
		No. 4	666 lbs.	No. 4	750 lbs.
		No. 5	589 lbs.	No. 5	725 lbs.
		No. 6	613 lbs	No. 6	790 lbs.
		No. 7	600 lbs	No. 7	885 lbs.
		No. 8	638 lbs.	No. 8	855 lbs.
Average	397⅓ lbs.	Average	626⅞ lbs.	Average	799 lbs.

With Sand. (1 of cement with 3 of sand.)

3 days.		7 days.		28 days.	
No. 1	210 lbs	No. 1	239 lbs.	No. 1	405 lbs.
No. 2	235 lbs	No. 2	296 lbs.	No. 2	413 lbs.
No. 3	213 lbs	No. 3	229 lbs.	No. 3	420 lbs.
No. 4	237 lbs	No. 4	305 lbs.	No. 4	424 lbs.
No. 5	220 lbs	No. 5	287 lbs.	No. 5	431 lbs.
No. 6	251 lbs.	No. 6	257 lbs.	No. 6	375 lbs.
No. 7	225 lbs.	No. 7	233 lbs.	No. 7	360 lbs.
No. 8	225 lbs.	No. 8	302 lbs.	No. 8	400 lbs.
				No. 9	393 lbs.
Average	227 lbs.	Average	268½ lbs.	Average	402⅓ lbs.

TEST MADE BY THE UNITED STATES BUREAU OF STANDARDS.

Cement .... Kosmos
Lab. No. 3842

Analysis.

Silica	20.74%
Oxide of iron	1.60
Oxide of aluminum	8.26
Lime	63.30
Magnesia	2.50
Sulphuric anhydride	1.68
Loss	2.50
Insoluble residue	0.48
Specific gravity	3.10

Fineness.

Passed 100 mesh sieve .... 98 %
Passed 200 mesh sieve 83.1%

Time of Set.

Initial .... 3 hours 50 minutes.
Final .... 7 hours 20 minutes.

Soundness Pats.

28 days in air .... O. K.
28 days in water .... O. K.
5 hours in steam .... O. K.

Tensile Strength (lbs. per sq. in.)

	7 days.	28 days.
Neat	672	645
	702	745
	678	680
Average	684	687
	345	465
1 cement	346	451
3 sand	365	470
Average	352	462

Water Used.

Neat ....25 %
Mortar 10.7%

ANALYSES OF LIMESTONE, SHALE AND CLAY.—Except as otherwise stated, the samples for the analyses of the following table were taken across the face of the various beds, layers, parts of formations sampled, the object being to obtain the average composition of the parts sampled. The limestone samples were with one exception taken by breaking chips from the face of the layer from top to bottom, and the clay samples by cutting a channel across the face and quartering down to convenient size, in the same manner as coal samples are collected. The analyses were all made for the Kentucky Geological Survey at the Kentucky Agricultural Experiment Station under the supervision of Dr. Alfred M. Peter, chief chemist.

Table of Analyses of Limestones, Shales and Clays of Jefferson County, Made by the Kentucky Geological Survey, Alfred M. Peter, Chief Chemist.

G-3661 Sedimentary clay from surface of glacial outwash deposit. Kosmosdale. Average sample from 7-foot face. Utilized for cement manufacture by the Kosmos Portland Cement Company.

G-3664 Sedimentary clay from alluvium or glacial outwash on intermediate river terrace, Louisville. Utilized by the Louisville Brick Company for common and press brick. Sample from bins ready for the press.

G-3665 Residual red clay from the Jeffersonville (Devonian) limestone 1 mile east of Whitner. Average sample from 6-foot face. Utilized by the Southern Brick & Tile Company, Whitner, for common brick and drain tile.

G-3657 Rosewood shale, upper part. Average sample from 10 feet of thickness. 1 mile west of Brooks and about that distance south of county.

G-3658 Same as 3657, but 20 feet lower in the formation.

G-3659 Same as 3657, but 50 feet lower in the formation.

G-3660 Same as 3657, but 100 feet lower in the formation.

G-3654 New Providence shale, lower part (green shale); Coral Ridge, utilized for brick by the Coral Ridge Clay Products Company.

G-3655 New Providence shale. Same locality as above, somewhat lower in the formation (blue shale).

G-3612 Jeffersonville limestone. Shanks quarry,* Louisville, bottom 12 feet, "Iron ledge." Not utilized except for road metal.

G-3613 Jeffersonville limestone. Same locality 4 feet below Spirifer gregarius zone.

*See detailed section of Shanks quarry.

G-3614 Louisville limestone, same locality. "Top blue ledge."
G-3615 Louisville limestone, same locality. "Gray ledge."
G-3616 Louisville limestone, same locality. "Oyster ledge."
G-3617 Louisville limestone, same locality. "Flint flagging."
G-3618 Louisville limestone, same locality. "7-foot ledge."
G-3619 Louisville limestone, same locality. "Lower blue ledge."
G-3620 Louisville limestone, same locality. "Hard ledge."
G-3621 Louisville limestone, same locality. "Hard curb."
G-3622 Louisville limestone, same locality. "22-inch ledge."
G-3623 Louisville limestone, same locality. "Blue captain."
G-3624 Louisville limestone, same locality. "Paving ledge."
G-3625 Louisville limestone, same locality. "Little Flagging ledge."
G-3626 Louisville limestone, same locality. "Big flagging."
G-3627 Louisville limestone, same locality. "1st curb ledge."
G-3628 Louisville limestone, same locality. "2nd curb ledge."
G-3629 Louisville limestone, same locality. "3rd curb ledge."
G-3630 Louisville limestone, same locality. "4th curb ledge."
G-3631 Louisville limestone, same locality. "Granddad ledge."
G-3663 Waldron shale. Cut on Shelbyville electric railroad at English Station, 1 mile east of Middletown.
G-3635 Laurel dolomite. Quarry* at Tucker. "9-inch ledge."
G-3636 Laurel dolomite. Quarry at Tucker. "Lower 9-inch ledge."
G-3637 Laurel dolomite. Quarry at Tucker. "8-inch ledge."
G-3638 Laurel dolomite. Quarry at Tucker. "11-inch ledge."
G-3639 Laurel dolomite. Quarry at Tucker. "15-inch ledge."
G-3640 Laurel dolomite. Quarry at Tucker. "18-inch ledge."
G-3641 Laurel dolomite. Quarry at Tucker, upper bed of road metal.
G-3642 Laurel dolomite. Quarry at Tucker, 16-foot bed of road metal.
G-3643 Laurel dolomite. Quarry at lowest bed in quarry.
G-3653 Upper shale of Osgood formation. Road just east of Bardstown pike 1 mile north of Fairmount church. See Plate 24.
G-3652 Upper limestone of Osgood formation. Same locality as 3653.
G-3651 Lower shale of Osgood formation. Same locality as 3653.
G-3650 Brassfield limestone. Highway on bluff 1 mile west of Seatonsville.
G-3662 Brassfield limestone. Branch of Harrods Creek 2 miles north northeast of O'Bannon.
G-3656 Hitz limestone member of Saluda limestone. Ridge west of Long Run 2 miles north of Boston.
G-3649 Saluda limestone. Quarry on highway on bluff 1 mile west of Seatonsville.

*See detailed section of Tucker quarry. Also Plates 25 and 59.

Table of Analyses.

Laboratory No. *	Moisture	Ignition (carbon dioxide, combined water, etc.)	Silica SiO_2	Alumina Al_2O_3	Ferric Oxide Fe_2O_3	Calcium Oxide CaO	Magnesium Oxide MgO	Manganus Oxide MnO	Sodium Oxide Na_2O	Potassium Oxide K_2O	Phosphorus Pent-oxide	Sulphur Tri-oxide SO_3	Titanium Dioxide TiO_2	Calcium Carbonate $CaCO_3$	Magnesium Carbonate $MgCO_3$	$SiO_2 \div (Al_2O_3 + Fe_2O_3)$
G-3661	2.09	5.53	64.48	17.27	4.40	.36	1.40	....	.77	2.65	Trace	None	.99	....	....	3.0
G-3664	1.62	6.11	65.92	15.30	4.40	.50	1.52	.16	.84	2.59	Trace	None	1.00	....	....	3.3
G-3665	1.58	4.20	74.10	10.38	4.48	.36	.85	.32	.43	1.72	Trace	None	1.00	....	....	5.0
G-3657	.44	5.30	68.36	13.19	3.68	3.10	1.34	n. e.	1.75	2.90	.12	.60	.85	5.53	....	4.1
G-3658	.23	3.79	68.44	15.52	4.80	.39	1.35	n. e.	1.61	3.55	.10	Trace	.92	....	....	3.4
G-3659	.57	3.97	67.30	15.82	5.20	.25	1.53	....	1.45	3.59	Trace	None	.86	....	....	3.2
G-3660	.76	4.31	63.56	18.81	5.68	.33	1.69	....	1.31	3.95	.10	None	.99	....	....	2.6
G-3654	.79	5.20	60.44	19.92	6.48	.28	2.01	n. e.	1.00	4.85	Trace	Trace	.80	....	4.22	2.3
G-3655	.60	5.96	60.40	19.73	4.72	.78	2.10	n. e.	.96	4.87	Trace	Trace	.83	....	4.41	2.5
G-3612	....	42.34	3.14	.18	.32	53.14	.65	....	....	....	Trace	.02	....	94.90	1.36	6.3
G-3613	....	42.24	4.34	.42	.16	49.25	2.46	....	....	....	Trace	Trace	....	87.95	5.17	7.5
G-3614	....	38.42	12.94	3.46	1.12	31.42	12.05	....	....	....	Trace	1.09	....	56.10	25.30	2.8
G-3615	....	37.32	15.04	2.82	.80	35.00	8.51	....	....	....	Trace	.64	....	62.50	17.87	4.2
G-3616	....	38.26	12.42	2.20	.64	41.13	5.14	....	....	....	Trace	.54	....	73.45	10.79	4.3
G-3617	....	31.55	26.56	1.16	.72	38.98	1.03	....	.11	.20	Trace	.28	....	69.60	2.16	14.
G-3618	....	36.85	15.90	1.74	.32	40.77	4.72	....	.16	.44	Trace	.43	....	72.80	9.91	7.7
G-3619	....	37.47	15.78	3.74	1.04	27.36	14.18	....	.19	.84	Trace	.91	....	48.85	29.76	3.3
G-3620	....	39.21	9.70	2.23	.61	44.64	3.75	....	....	....	Trace	.51	....	79.70	7.88	3.4
G-3621	....	41.11	5.64	2.22	.74	47.34	3.97	....	....	....	Trace	.36	....	84.54	8.34	1.9
G-3622	....	41.47	5.24	1.60	.72	44.96	6.18	....	....	....	Trace	.09	....	80.30	12.98	2.3
G-3623	....	40.83	6.82	2.28	.16	45.92	4.42	....	....	....	Trace	.03	....	82.00	9.24	2.8
G-3624	....	39.67	9.26	3.12	.16	41.28	6.60	....	.05	.56	Trace	.50	....	73.70	13.86	2.8
G-3625	....	41.61	4.54	1.72	.08	50.12	2.02	....	....	....	Trace	.33	....	89.50	4.24	2.5
G-3626	....	40.30	7.70	1.62	.40	45.78	4.16	....	.05	.31	Trace	.15	....	81.75	8.74	3.8
G-3627	....	41.02	6.54	3.72	.40	41.28	7.36	....	....	....	Trace	1.34	....	73.70	15.45	1.6
G-3628	....	40.39	8.48	2.24	.56	43.34	6.26	....	.10	.43	Trace	.38	....	77.40	13.08	3.
G-3629	....	40.98	6.36	1.56	.56	46.48	4.52	....	....	....	Trace	.30	....	83.00	9.45	3.
G-3630	....	41.52	5.90	1.60	.64	41.94	8.05	....	.08	.40	Trace	.41	....	74.90	16.91	2.6
G-3631	....	42.17	3.40	1.15	.35	51.41	.88	....	....	....	Trace	.35	....	91.80	1.85	2.3
G-3663	1.05	25.53	29.54	12.43	2.88	14.92	10.43	....	.39	3.17	Trace	2.62	.49	26.63	21.90	1.9
G-3635	....	43.18	6.82	1.32	1.04	31.75	17.09	....	....	....	Trace	.26	....	56.70	35.89	2.9
G-3636	....	42.96	6.34	1.54	1.04	32.14	15.67	....	....	....	Trace	.31	....	57.40	32.91	2.5
G-3637	....	41.90	7.50	2.10	.80	32.31	15.36	....	....	....	Trace	.33	....	57.70	32.25	2.6
G-3638	....	42.55	6.22	1.54	.64	33.49	15.04	....	....	....	Trace	.38	....	59.80	31.58	2.9
G-3639	....	43.59	5.62	1.28	.80	31.69	17.29	....	....	....	Trace	.32	....	56.60	36.31	2.7
G-3640	....	44.94	2.58	.42	.64	33.88	17.04	....	....	....	Trace	.18	....	60.50	35.78	2.4
G-3641	....	44.72	3.94	.80	.80	31.08	17.40	....	....	....	Trace	.29	....	55.50	36.54	2.5
G-3642	....	45.46	1.84	.86	.80	32.82	16.19	....	....	....	Trace	.88	....	58.60	34.00	1.
G-3643	....	40.64	9.06	2.50	1.76	28.72	16.05	....	.03	.86	Trace	1.24	....	51.30	33.70	2.1
G-3653	....	32.32	21.56	8.44	2.08	21.20	13.20	....	.10	2.29	Trace	.06	....	37.85	27.70	2.0
G-3652	....	41.19	7.92	2.61	1.44	29.51	16.58	....	....	....	.11	.22	....	52.70	34.65	2.
G-3651	1.52	13.08	46.48	18.22	3.52	6.55	5.07	n. e.	.75	5.52	Trace	None	.74	11.69	10.65	2.1
G-3650	....	43.46	2.80	.34	.72	45.08	7.28	....	....	....	Trace	.09	....	80.50	15.21	2.6
G-3662	....	43.28	1.12	.10	.32	53.12	1.78	....	....	....	Trace	None	....	94.85	3.73	2.7
G-3656	....	41.64	4.10	.98	.56	48.97	2.44	....	....	....	Trace	.40	....	87.45	5.12	2.7
G-3649	....	36.83	16.12	4.57	1.28	25.51	14.78	....	.10	1.26	.25	.33	....	45.55	30.89	2.8
G-3646	....	36.82	12.16	3.87	1.76	40.54	4.37	....	....	....	.27	.49	....	72.40	9.18	2.2
G-3647	....	32.67	17.32	5.39	2.72	34.80	4.90	....	.21	1.50	.33	1.19	....	62.15	10.24	2.1
G-3648	....	34.41	15.74	5.15	1.44	36.60	4.86	....	.17	1.37	.39	.38	....	65.35	10.16	2.4
G-3644	....	39.59	2.18	2.90	1.20	49.56	1.77	.24	.08	.14	.89	.25	....	88.44	3.69	....
G-3645	....	42.17	1.98	.85	.80	47.71	4.68	....	....	....	.81	.25	....	85.20	9.83	1.2

*Serial numbers of the Kentucky Agricultural Experiment Station.

G-3646 Waynesville limestone. Upper 7 feet of quarry on Brush Run 2¼ miles east of Seatonsville. See Plate 10.

G-3647 Waynesville limestone. Middle 3 feet 6 inches of quarry on Brush Run 2¼ miles east of Seatonsville.

G-3648 Waynesville limestone. Lower 5 feet of quarry on Brush Run 2¼ miles east of Seatonsville.

G-3644 Limestone in Arnheim formation. Upper cross bedded layer Brush Run east of Seatonsville.

G-3645 Limestone in Arnheim formation. Lower cross bedded layer Brush Run east of Seatonsville.

OIL AND GAS.

The New Albany shale yields a little gas in the southwest part of the county and is a potential source of considerable oil which it yields on distillation. The ability of the shale to yield oil and gas when heated is known to fishermen on the river banks who use this shale with driftwood for fires in chilly weather.

Samples of the shale were collected from the bottom 8 feet exposed in excavating for the enlargement of the Louisville canal at its west end, from the bank of Falling Run, Indiana, a short distance above its mouth, and from the river bank just above the Kentucky and Indiana bridge at New Albany. These samples were subjected to tests for the determination of their bituminous and other useful contents with the results stated below. The tests were made by David T. Day of the United States Bureau of Mines.

Results of Tests for Oil, Gas, and Ammoniacal Products on Samples of New Albany Shale Collected at Louisville, Kentucky, and New Albany, Indiana.

Location of Shale	Amount of shale used	Yield of oil per ton	Yield of gas per ton	Yield of water per ton	Yield of ammonia per ton	Color of shale
	Oz.	Gal.	Cu. Ft.	Gal.	Lbs.	
Louisville, Ky. West end of canal. Average sample of the bottom 8 feet of shale.	6	11.2	1916	4.2	0	Black
New Albany, Ind. Just above end of K. & I. Bridge.	6	11.9	1197	6.3	0	Black
New Albany, Ind. Falling Run.	6	9.1	958	4.2	0	Black

The average oil content of the shale sampled computed from these tests is 10.7 gallons per ton. Assuming 2.6 as the specific gravity of the shale, a cubic yard of it weighs about 2 tons and therefore contains 21.4 gallons of oil. A square mile of the shale, its thickness being 100

feet, contains 309,760,000 cubic yards. Its oil content, therefore, is 6,628,864,000 gallons or 157,830,095 barrels of 42 gallons. This calculation is based on the assumption that the oil content of the full thickness of the shale is as high as that of the portion sampled. The sampled portion represents about ½ the full thickness, and the remainder looks as good as that sampled. Compared with the oil shale of Scotland and with similar shale in Colorado and Utah, however, the oil and gas content of the New Albany shale is low. According to the Stuart-Town Society of Chemical Industry, p. 100, 1889, quoted by Duden,* the oil shale at Broxburn, Scotland, yields 135 liters or about 35 gallons of oil per ton, and about 57 cubic meters, or about 1,952 cubic feet of gas per ton. According to Woodruff and Day,† different samples of the oil shale of Colorado and Utah contain from 10.4 to 35.5 gallons of oil per ton, the average of all samples from layers of the shale 3 feet or over in thickness being 22.5 gallons per ton. Oil and gas and ammoniacal substances are extracted from the oil shales of Scotland, France and Germany by distillation, but in view of the low price of petroleum and of the quantity of richer oil shale in the world, profitable extraction of oil or gas from the New Albany shale would be impossible at present, notwithstanding the great quantity of those substances in the shale. However, it is not improbable that the exhaustion of the oil pools and of the richer oil shale deposits of the country and of the world will eventually lead to the utilization of the Devonian black shales which are, therefore, to be counted as most important ultimate oil reserves.

As shown in the table, no ammoniacal compounds are present.

A small quantity of natural gas is obtained from the New Albany (black) shale by shallow wells in the southwest corner of the county. Wells penetrating the top of the shale at the depth of about 100 feet usually yield gas enough for a household and a few persons have such wells. Oil is not reported from any of these wells.

*Duden, Hans. Ind. Dept. Geol. & Min. Res., 21st Ann. Rept., p. 116, 1896.

†Woodruff, E. G., and Day, David T. Oil Shale of Northwestern Colorado and Northeastern Utah. Bull. 581-A, U. S. Geol. Survey, 1914.

In 1886 and 1887 gas in comparatively large quantities was struck in wells drilled into the New Albany shale in Meade County, Kentucky, about 25 miles southwest of Louisville. The field was located on the south bank of the Ohio River on a well defined dome. The gas was piped to Louisville and used for a number of years and is still used to a small extent. Salt water followed the gas in the shale, and as the gas was exhausted took its place in the wells. At present the gas is nearly exhausted and the wells are mostly producing salt water.

In regard to the possibilities of oil and gas in other parts of the county and other strata, two factors bearing on such occurrence may be set forth. The first of these is the existence of rock of such texture as to serve as a reservoir for oil or gas, and the second is such structure or lay of the strata as to facilitate local accumulation of them.

Accumulations of oil or gas in commercial quantities usually exist in more or less open textured sandstone or conglomerate, as in West Virginia and Pennsylvania; but less commonly in limestone or dolomite, as in Western Ohio and in Indiana.* As already shown in the description of stratigraphy, no sandstone is known to underlie Jefferson County except a calciferous sandstone which yields the sulphur water in the deep wells at Louisville and Fisherville. This sandstone has nowhere been known to bear oil except in very small quantities, although it has produced some high pressure gas at several points in Kentucky. In Ohio and Indiana, oil and gas have been found in large quantities in the "Trenton" limestones. A well drilled in Jefferson County to a depth of 1,000 feet below the base of the New Albany shale would pass entirely through the "Trenton." The deep wells in Louisville passed far below the base of it. The "Trenton" in Ohio and Indiana, wherever it is oil and gas bearing, is dolomitic in character, a condition which does not obtain in Kentucky. At no point in Kentucky has the "Trenton" proved productive, nor is it likely to. In the oil fields of Kentucky, however, including the Menifee, Wolfe and Morgan County fields in Eastern Kentucky, the Wayne County field in Southern Kentucky, and the Allen, Barren and Ohio County fields in Western Kentucky,* oil and gas are produced from limestones either a short distance above the New Albany shale or a short distance below it. In Wayne County it is above the shale and, in the others mentioned, just below it, either in Devonian or Niagaran limestone. There would be scarcely a possibility of oil in Jefferson County above the New Albany shale, but the opposite is true in regard to the limestones below it which are oil bearing elsewhere. These could be reached by wells of very moderate depth (100 to 150 feet below the base of the black shale would be all that would be required) and if favorable structure can be found it would seem worth while to test these limestones for a possible supply of oil.

*In the Kentucky fields nearly all the oil and gas are found in limestones.—J. B. H.

With respect to geologic structure the conditions in portions of the county would seem to be favorable. In many regions oil and gas accumulate on the summits and flanks of anticlines or upward bending folds in the strata. Such a fold is the Springdale anticline and the small anticlinal spurs or noses east of Floyds Fork, and in the Knob region in the southern part of the county as shown by the structure contours on the map.

While it would be rash to say positively that oil or gas in commercial quantities are present in any of the rocks of the county, yet it is safe to say at least that there are chances for their occurrence. If any test drilling should be done the wells should be located on or near the anticlines shown on the map and drilled to a depth of 100 to 150 feet below the black shales unless oil is struck at a more shallow depth. The most hopeful location would probably be the anticlines in the southern part of the county east of the Norton Hills where the structural conditions seem most favorable either for gas in the New Albany (black) shale, or oil or gas in the limestones just below.

*These constitute nearly all the producing area excepting those in Lawrence and Martin counties.

SOIL.

Several kinds of soil exist in Jefferson County. In most of the county the soil is mainly derived from limestone, and is consequently a clayey loam of high to medium fertility, yielding excellent crops of wheat, corn, grass, potatoes and tobacco, which are the main farm products of the county.

The soil from the New Albany shale, as in the vicinity of Lyndon and Buechel, is a stiff, whitish, clayey loam likely to be wet in rainy times and hard in dry times. Under favorable conditions it appears to yield fair crops of grass, corn, etc. The soil over the large area of New Albany shale north of the Knobs is mixed with sandy material washed from the knobs and is less clayey apparently than the pure shale soil. This area was formerly an extensive swamp but has been mostly reclaimed by ditching and by dredging Pond Creek, so that it has been converted into good farming land excellently adapted to corn, grass and vegetables.

The soil from the New Providence shale is similar to that from the New Albany. The Rosewood shale probably yields clayey loam of rather more sandy character than that from the other two shale formations. This soil lies on the steep slopes of the knobs and is therefore not much cultivated, but mostly forested.

The tops of the ridges and knobs in the southern part of the county have a limestone soil from the Warsaw limestone. This is a light, clayey loam yielding good crops of corn, vegetables and fruit. The soil and situation seem especially adapted to peaches and there are many fine producing orchards.

The alluvium along the streams and on the broad river terrace of glacial outwash is a sandy loam of high original fertility, but owing to its favorable situation has been considerably depleted in fertility by long continued cropping. Corn, grass, wheat and vegetables thrive and the soil is suitable for any crops grown in this latitude.

The principal branches of farming in the county are growing grain, potatoes on a large scale, tobacco, truck crops for the Louisville markets, and dairying and stock raising.

Plate 64.
Upper limestone of the Osgood showing contact with lower shale. Spring at contact. Near the Waterford road, just southeast of county, and about 1 mile east of Floyds Fork. Looking north.

WATER RESOURCES.

SURFACE WATER.—The streams of Jefferson County except Ohio River and Floyds Fork are small. Some of them are on rock beds and have little or no flow except after rains. However, depressions at intervals in these stream beds are filled with water and there is probably underground seepage from one to another. These pools survive even during protracted drouths and furnish water for stock, but owing to stagnation, this water is of poor quality. The principal creeks such as Harrods, Goose, Little Goose, Cedar and Pond Creeks, are generally fed by springs and have a permanent, though small flow, even in dry weather. Floyds Fork is a larger stream and has a rather large flow except after long drouths when the flow is small, as was the case late in the summer of 1914. The supply even then was sufficient for stock and for such other uses as were required, as for steam boilers, etc. The water supply of Louisville is drawn from Ohio River 2 or 3 miles above the city, the water being filtered before use. Discharge tables showing the amount of water flowing in the river at Louisville for various periods are given in connection with the discussion of water power.

GROUND WATER.—The original source of ground water is the rain, that is in part absorbed by the earth. Such water percolates into the rocks through cracks or porous layers to considerable depths. In some places a particularly favorable stratum, such as a coarse-grained, porous sandstone lying between two impervious strata and outcropping on high ground in one locality, is carried by the dip below the surface at a distant but lower point. Water entering such a stratum at its outcrop follows the dipping stratum beneath the surface to some distant point where the water is under high pressure. A well drilled at such a point will strike the water, which may be forced by the pressure to flow out at the surface. Though structural conditions in the western and central parts of Jefferson County are favorable for artesian wells, there is no porous stratum to serve as a water carrier and no strong flowing wells may be expected, although a large volume of water may rise nearly to the surface in some wells.

Rain water having penetrated slowly the solid rock to various depths up to several hundred feet and having met a layer of clay or some other impervious rock that retards or prevents its further passage downward, may follow the surface of the impervious layer to its outcrop and issue as a spring. The lower shale of the Osgood formation is such a water carrier, and springs are common at its horizon, as shown in Plate 64. The lower part of the Louisville limestone is also a water-bearing horizon, the water being partly held by the underlying Waldron shale. Springs may issue also at higher horizons in the Louisville limestone. A boring to the impervious stratum or to some porous water course in the ground is likely to encounter considerable water.

The principal horizons at which water may be expected are the top of the Louisville limestone immediately below the New Albany (black) shale, the bottom of the Louisville limestone or the top of the Waldron shale, or the top of the lower shale of the Osgood. The depth at which these horizons may be reached can be calculated by the method explained under geologic structure. Wells have been obtained in the top of the Louisville in the black shale area north of the knobs, and wells in the shale of the Osgood have been obtained in the vicinity of Buechel and perhaps at Fern Creek Station. The Richmond strata in the eastern part of the county supply a few springs and wells yielding a permanent supply of water. Supplies at least sufficient for domestic use can generally be obtained by digging to the depth of 20 to 40 feet into the Richmond. The glacial outwash terrace deposit still supplies many wells 20 to 100 feet deep in Louisville. Wells drilled to a depth of about 100 feet in this material by power companies of Louisville have obtained plenty of water for cooling machinery.

CHEMICAL CHARACTER OF THE WATERS.—The water from the sandstone of the deep wells, supposed to be the St. Peter sandstone, is highly sulphurous and saline, as is shown by the analysis of water from the Fisherville well.

Analysis of Water From the St. Peter (?) Sandstone in the Fisherville Well, 1½ Miles West of Fisherville.* Analysis by L. D. Kasterbone, Louisville Medical College.

	Parts Per Million
Silica (SiO_2)	32
Oxides of iron and aluminum ($Fe_2O_3 + Al_2O_3$)	24
Calcium (Ca)	1060
Magnesium (Mg)	550
Sodium and potassium (Na + K)	2266
Carbonate radicle (CO_3)	0
Bicarbonate radicle (HCO_3)	1320
Sulphate radicle (SO_4)	1610
Chlorine (Cl)	5014
Organic and volatile matter	28
Total	11,407
Free carbon dioxide (CO_2)	392
Free hydrogen sulphide (H_2S)	111

Water from St. Patrick well, in Third Avenue, Louisville, is similar in composition. Medicinal properties are claimed for both waters. A resort is operated at Fisherville, and water from St. Patrick well is bottled and sold in Louisville.

The general composition of water from the various formations in the county has not been determined by analysis. The water from limestone or other calcareous rocks is of course hard. The water in general, however, is probably similar to that from the same formations in Southwestern Ohio, the average chemical composition of which is given in the subjoined table:

*This analysis originally stated by the analyst in grains per gallon in conventional combinations has been calculated to ionic form in parts per million.

Average Chemical Composition of Water From Various Strata in Southwestern Ohio.*

Mineral content in parts per million

Principal water-bearing stratum.	Number of analyses averaged	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chlorine (Cl)	Total solids
Alluvium	63	15	1	90	30	......	0	380	100	60	500
Gravel	17	25	1	90	30	20	0	400	50	25	440
"Niagara"	20	20	.5	80	40	20	0	360	80	25	440
"Clinton"	7	15	.2	......	......	......	0	430	100	50	......
Richmond and Maysville	25	20	.2	190	70	140	0	380	300	160	1,100
St. Peter	6	30	10	5,000	800	14,000	0	350	700	36,000	57,000

Percentage composition of anhydrous residue

Principal water-bearing stratum.	Number of analyses averaged	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chlorine (Cl)	Total solids
Alluvium	......	3	0	18	6	**4	37	......	20	12	......
Gravel	......	6	0	20	7	5	45	......	11	6	......
"Niagara"	......	4	0	18	9	5	40	......	18	6	......
"Clinton"	......	......	......	......	......	......	......	......	......	......	......
Richmond and Maysville	......	2	0	18	6	13	18	......	28	15	......
St. Peter	......	0	0	9	2	25	0	......	1	63	......

The following remarks by Dole† regarding the ground waters of Southwestern Ohio are to a great extent pertinent to conditions in Jefferson County:

"The best source of large amounts of water for industrial purposes in this region is Ohio River, whose waters are much lower in dissolved solids than its tributaries from Southwestern Ohio and only from one-fifth to one-third as high in dissolved solids as the ground waters of low mineral content. Practically all the surface waters are lower in mineral content than the ground waters and consequently are better for industrial use. In addition to dissolved matter, the water of the Ohio River averages 230 parts * * * per million of suspended solids, but it would be much less expensive to remove the suspended matter from these waters than to soften available ground waters that do not contain suspended matter. If the turbidity were removed by sedimentation or by filtration the surface waters could

*Fuller, M. L., and Clapp, F. G. The underground waters of Southwestern Ohio, with a discussion of the chemical character of the waters by R. B. Dole: U. S. Geol. Survey Water Supply Paper 259, p. 212, 1912.

**Estimated.

†Idem, p. 216.

be classified as good to fair for boiler use and most of them could be used without further treatment.

"The waters from the alluvium, gravel, till, 'Niagara' limestone (Niagaran rocks of Jefferson County), and 'Clinton' (Brassfield) limestone, are simliar in mineral content and in the character of their dissolved matter. Dissolved solids range from 300 to 600 parts per million and average about 500 parts, chlorides from 2 to 200 parts, sulphates from a trace to 300 parts, and bicarbonates from 240 to 600 parts. The waters are hard, but they can readily be softened, and in their natural condition they range from fair to bad for boiler use; they deposit considerable scale and some of them are corrosive, but they do not foam under ordinary conditions of boiler operation.

"The waters from the Richmond and Maysville formations and from the Point Pleasant are distinctly less desirable as industrial supplies, being much higher in incrustants, chlorides, and sulphates. Though some of the waters from the Richmond and Maysville are as low in incrustants as some of the waters from the later beds, the results of the few analyses available indicate that this is not their general condition.

"The St. Peter sandstone yields water so heavily mineralized as to be unfit for industrial use except for cooling, and even for that purpose the water would be corrosive.

" * * * Nothing in the averages of the analyses of fresh underground waters indicates that they are not suitable for drinking and for general domestic use, though those from the earlier formations are very hard. Consideration of the individual analyses, however, shows that some of the waters contain so much iron that they would stain fabrics washed in them. * * * "

WATER POWER AT LOUISVILLE, KY.

The following brief discussion of the water power of the Falls of the Ohio at Louisville, Ky., has been prepared by Mr. H. J. Jackson, of the water-resources branch of the United States Geological Survey.

In a paper read at the Fifth Annual Convention of the American Society of Civil Engineers in Louisville, Ky., May 21 and 22, 1873, Morris S. Belknap,* C. E., stated:

"From being long regarded as a great and serious obstacle to the commerce of the city, the Falls, as soon as it became apparent that Louisville was to be a manufacturing town, attracted considerable attention from those interested, as a possible source of power, and in late years much has been said and written of the millions of horse-power that were allowed daily to waste without application to any useful purpose. The interest thus manifested has in the past provoked several inquiries into the possibility of utilizing the vast force thus lost, but none have, it is thought, offered the most economical solution, and all have tacitly assumed a financial success, without seeking to answer the important question, 'Will it Pay?' "

It is not proposed to answer Mr. Belknap's question in this paper, but data prepared by the Survey relative to the discharge of the Ohio are presented for the information of those interested in the possibilities of power development at Louisville.

Four tables of discharge are given which were computed by the Survey to mean daily gage heights furnished by the Mississippi River Commission and a discharge rating curve determined by the Survey. The daily gage heights are the means of two readings a day, at 8 a. m. and 4 p. m., on the lower-lock gage at Louisville. The rating curve is well defined and is based on 14 discharge measurements made by the Survey during the calendar years 1910-1912, and discharge measurements made by J. F. Coleman of the U. S. Army Engineer Corps in 1892.

TABLE 1.—*Discharge of Ohio River at Louisville, Ky., for the years ending September 30, 1905-1914.*—

*Am. Soc. Civ. Eng. Trans., vol. 2, p. 262, 1874.

This table gives the average, highest and lowest mean discharge for certain units of time during the ten-year period, October 1, 1904, to September 30, 1914. It should be observed that some of the figures representing maximum and minimum mean daily discharge refer only to nine of the ten years.

TABLE 2.—*Monthly discharge of Ohio River at Louisville, Ky., for the year ending September 30, 1905.*—The year 1905 was the year of lowest mean annual discharge during the ten-year period 1905-1914, and may be taken as a representative low-water year. The minimum mean daily discharge for the year is not given because the mean monthly discharge was estimated during the month when the minimum occurred.

TABLE 3.—*Monthly discharge of Ohio River at Louisville, Ky., for the year ending September 30, 1907.* —1907 was the year of largest mean annual discharge in the ten-year period 1905-1914, and may be taken as a representative high-water year.

TABLE 4.—*Days of deficiency in discharge of Ohio River at Louisville, Ky., in the years ending September 30, 1906-1914.*—Table 4 shows the number of days in each year that the mean daily discharge was less than that given in the column of discharge. By subtraction the table gives the number of days in each year that the mean daily discharge was between the amounts given in the column of discharge, and also by subtraction, the number of days that the mean daily discharge was equal to or greater than the amounts given. For example, in the year ending September 30, 1911, the mean daily discharge was less than 50,000 second-feet on 183 days, was between 50,000 and 65,000 second-feet for 20 days, and was equal to or greater than 50,000 second-feet for 182 days. The gage height, referred to the lower gage at Louisville, corresponding to each discharge is given in the column headed gage heights. For convenience of reference, the theoretical horse-power per foot of fall corresponding to discharges below 80,000 second-feet is also given, although no studies have been made by the Survey to determine to what extent it would be economical to develop such power.

If the ordinary flow of a stream for a given period be defined as the median of quantities of mean daily dis-

charge for the period arranged in order of magnitude, it will be observed from the deficiency table that the ordinary flow of Ohio River at Louisville, Ky., during the years ending September 30, 1906-9 and 1911-14 ranged from about 50,000 second-feet in the year ending September 30, 1911, to approximately 130,000 second-feet in the year ending September 30, 1912. In considering the ordinary flow for one year it will be observed that it is the 183d quantity in a table of mean daily discharge in which the quantities are arranged in order of magnitude.

The years for which discharge data are given do not include the maximum range of stage at Louisville, which as referred to the lower-lock gage, is about 70 feet. A stage of 2.0 feet was reported in October, 1895, and 72.0 feet in February, 1884.

According to the rating curve prepared by the Survey, a stage of 2.0 feet corresponds to a discharge of 4,130 second-feet, but comparisons with the computed discharge at Cincinnati and Evansville indicate that the discharge at Louisville was not that low in October, 1895. The computed minimum mean daily discharge of Ohio River at Cincinnati in October, 1895, is about 4,400 second-feet, and at Evansville about 6,100 second-feet; these figures indicate that the minimum at Louisville was approximately 5,200 second-feet. The discharge corresponding to a stage of 72.0 feet at Louisville is about 792,000 second-feet.

Equalling in importance the volume of discharge in any consideration of power, is available fall or head, concerning which the Survey has collected no data at Louisville, but the following quotations from papers by Army Engineers will throw some light on this question.

In his paper "Works at the Falls of the Ohio River, Louisville, Ky.,* Maj. J. C. Oakes, of the U. S. Army Engineer Corps, states:

"The obstruction to navigation of the Ohio River known as the 'Falls of the Ohio' lies opposite Louisville, Ky., and is formed by an irregular mass of limestone underlying the entire width of the river. The head of the falls is approximately 602 miles by river from Pittsburg, Pa., and 364 miles from Cairo, Ill. This mass

*In Professional Memoirs, vol. 6, No. 29, p. 563, September-October, 1914.

of rock forms a natural dam, creating a deep pool above and a fall at low water stages of 27 feet from head to foot of falls. * * * The gage readings above the dam vary from 1.7 to 46.7 feet.

"The river at the head of the falls is about 1 mile wide, while below Louisville for some 50 miles its width is approximately one-half as great. During floods the contraction of the river below causes the lower pool to rise more than twice as fast as the upper pool, until at a 16-foot stage upper pool there is generally a fall between head and foot of falls of about 2 feet."

The zero of the upper gage at Louisville is 403.0 feet above main sea level, and the zero of the lower gage is 376.1 feet above mean sea level as reported by the Mississippi River Commission.

In a special report on the improvement of the Falls of the Ohio, dated February 10, 1882,* Maj. G. Weitzel, of the Corps of Engineers, states:

"There were three channels over these obstructions, known as the Indiana, Middle and Kentucky chutes.

"The former is the main and longest channel, and was the one most navigated. It runs near the Indiana shore, between it and Goose Island, and makes a large bend near the foot of the fall, called the Big Eddy. It was 4,659 yards, or about 2 2/3 miles long. At extreme low stages, about one-half of its total fall, that is, 13 feet, occurred in the first 1,253 yards, or about seven-tenths of a mile, and about two-thirds of its fall, that is, 17½ feet, occurred in the first 1,986 yards, or about 1 1/7 miles. When the water rose 7 feet at the crest of the falls above extreme low water, it rose about 18½ feet at the foot of the channel, and the difference of level between the water surfaces in the two pools was about 13½ feet. * * * The Middle chute begins about the middle of the river and passes down between Goose and Rock Islands. The length of this channel is about 3,800 yards, or 2 1/6 miles long, and about 22 feet, or almost the entire fall is in the last 500 yards. All boats could ascend it when the water at the head rose about 13 feet. The rise in the pool below then amounted to about 29 feet, and the

*Annual Report of the Chief of Engineers, U. S. Army, 1882, part II., pp. 1881-1882.

difference of level between the water surfaces of the two pools was then reduced to about 9 feet.

"The Kentucky chute lies nearer to the Kentucky shore, and passes down between it and Rock Island. Its condition was similar to the Middle chute and it is navigable a little later than the Middle chute. Almost the entire fall is in the last 185 yards. The shortest line across this natural dam is via the Middle and Kentucky chutes, and is about 3,300 yards, or 1 11/12 miles long.

"The observations which were made and recorded established the fact that on an average the falls were not navigable ten and a half months per annum.

"The fact that these obstructions were navigable at some stages and not at others arises from the circumstances (as indicated above) that when the river rises both pools rise, but not equally. The lower one rises by a greater amount in a given time than the upper one. A similar law exists as the river falls; that is, the lower pool falls more in a given time than the upper one."

In conclusion it may be said that in view of the enormous floods to which the Ohio River is subject, the large range of stage at Louisville, the rapid loss of head with increase of flow resulting from the comparatively rapid rise of the tail water, and in view also of the expensive character of power installation at Louisville, the feasibility of any large development at this point is a problem, the solution of which must be left to the future.

Table 1.

Discharge of Ohio River at Louisville, Ky., for the Years Ending Sept. 30, 1905-1914.

(Drainage area, 91,200 square miles.)

	Average	Highest		Lowest	
	Sec.-ft.	Date	Sec.-ft.	Date	Sec.-ft.
Mean Annual Discharge	121,000	1907	166,000	1905	82,500
Maximum Mean Daily Discharge	a 553,000	April 2 1913	770,000	May 17 1905	432,000
Minimum Mean Daily Discharge	b 14,400	Nov. 17 1906	27,600	Sept. 30 1914	b 7,600
Mean Monthly Discharge	121,000	January 1907	468,000	October 1908	9,770

a For the years ending Sept. 30, 1905-1909, and 1911-1914 only. Discharge during period of maximum discharge in 1910, estimated because of ice gorge.

b For the years ending Sept. 30, 1906-1914 only. Mean monthly discharge for October, November and December, 1904, estimated because of apparent error of computed discharge indicated by comparison of records for Louisville, Ky., with those for Cincinnati, Ohio, and other points in the Ohio River basin.

Table 2.

Monthly Discharge of Ohio River at Louisville, Ky., for the Year Ending September 30, 1905.

(Drainage area, 91,200 square miles.)

MONTH	DISCHARGE IN SECOND-FEET				RUN-OFF
	Maximum	Minimum	Mean	Per square mile	Depth in inches on drainage area
October	....	....	10,400	0.114	0.13
November	....	....	10,800	.118	.13
December	....	....	11,600	.127	.15
January	134,000	32,400	65,800	.721	.83
February	....	....	70,600	.774	.81
March	432,000	105,000	261,000	2.86	3.30
April	261,000	65,200	110,000	1.21	1.35
May	432,000	57,100	184,000	2.02	2.33
June	149,000	54,200	81,900	.898	1.00
July	136,000	57,800	79,700	.874	1.01
August	110,000	36,100	61,000	.669	.77
September	62,000	25,800	40,000	.439	.49
The year	432,000	....	82,500	.904	12.30

NOTE.—Mean monthly discharge for October, November and December, 1904, estimated because of apparent error of computed discharge indicated by comparison of records for Louisville, Ky., with those for Cincinnati, Ohio, and other points in the Ohio River basin. Mean discharge February 2-27, 1905, not estimated because of ice.

Table 3.

Monthly Discharge of Ohio River at Louisville, Ky., for the Year Ending September 30, 1907.

(Drainage area, 91,200 square miles.)

MONTH	DISCHARGE IN SECOND-FEET				RUN-OFF
	Maximum	Minimum	Mean	Per square mile	Depth in inches on drainage area
October	92,000	40,600	56,400	0.618	0.71
November	250,000	27,600	87,600	.961	1.07
December	338,000	43,200	159,000	1.74	2.01
January	713,000	205,000	468,000	5.13	5.91
February	217,000	90,300	136,000	1.49	1.55
March	633,000	153,000	374,000	4.10	4.73
April	196,000	112,000	142,000	1.56	1.74
May	214,000	81,400	141,000	1.55	1.79
June	363,000	63,700	197,000	2.16	2.41
July	174,000	57,800	95,900	1.05	1.21
August	124,000	40,600	65,400	.717	.83
September	79,000	40,600	54,400	.596	.67
The year	713,000	27,600	166,000	1.82	24.63

Table 4.

Days of Deficiency in Discharge of Ohio River at Louisville, Ky., in the Years ending September 30, 1906-1914.

Gage Heights.	Discharge in sec.-ft.	Theoretical Horsepower per foot fall	Days of Deficiency in Discharge.								
			1905-6	1906-7	1907-8	1908-9	a 1909-10	1910-11	1911-12	1912-13	1913-14
2.99	8,000	909	......	......	......	0	....	......	......	......	b 1
3.11	8,500	966	......	......	0	13	....	0	......	......	6
3.22	9,000	1,020	......	......	2	16	....	1	......	......	7
3.44	10,000	1,140	......	......	2	21	....	9	......	0	9
3.77	11,500	1,310	......	......	4	25	....	14	......	6	9
4.08	13,000	1,480	......	......	10	47	....	30	......	13	14
4.49	15,000	1,700	......	......	16	59	....	38	......	19	29
5.08	18,000	2,040	0	......	23	66	....	53	......	23	64
5.82	22,000	2,500	2	......	28	89	....	73	0	45	94
6.70	27,000	3,070	22	0	38	112	....	94	3	81	116
7.70	33,000	3,750	69	6	51	119	....	134	13	110	129
8.81	40,000	4,540	106	9	81	132	....	158	26	140	153
10.30	50,000	5,680	155	62	133	161	....	183	65	167	168
12.38	65,000	7,380	186	104	158	173	....	203	110	190	178
14.32	80,000	9,090	216	125	174	194	....	207	134	220	199
16.76	100,000	....	247	155	192	225	....	218	159	245	221
19.06	120,000	....	274	191	210	251	....	243	172	261	234
21.25	140,000	....	293	212	226	271	....	256	189	270	246
23.35	160,000	....	308	237	240	292	....	269	220	276	262
26.36	190,000	....	327	261	272	307	....	284	255	292	286
29.25	220,000	....	339	294	284	311	....	309	278	311	306
32.92	260,000	....	350	307	295	324	....	325	304	320	328
36.42	300,000	....	355	313	303	333	....	341	319	322	346
40.59	350,000	....	357	325	320	341	....	348	333	326	358
44.55	400,000	....	358	333	332	347	....	357	341	328	361
49.12	460,000	....	360	339	350	357	....	365	350	332	365
53.54	520,000	....	365	343	361	358	....	......	360	340	......
59.22	600,000	....	......	352	366	365	....	......	366	344	......
66.01	700,000	....	......	362	......	......	....	......	......	356	......
72.52	800,000	....	......	365	......	......	....	......	......	365	......

a Discharge estimated for part of year because of ice gorge.
b Discharge 7,600 second-feet on Sept. 30, 1914.

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